Watershed Planning Course
2003 Planning Associates Program
14-18 July, 2003 – Atlanta, GA
Watershed Planning, Assessment, and Decision-making

- **"We need to move to a watershed approach as it applies to water resources projects so that each of our projects fits into the context of a regional plan."**

LTG Robert Flowers – e-mail to USACE on 19 JUN 02, commenting on his testimony to the Senate Environment and Public Works Committee hearing on Corps of Engineers water resources programs.

ERDC Engineer Research and Development Center

Steve Ashby, PhD
Steven.L.Ashby@erdc.usace.army.

and in Conclusion …

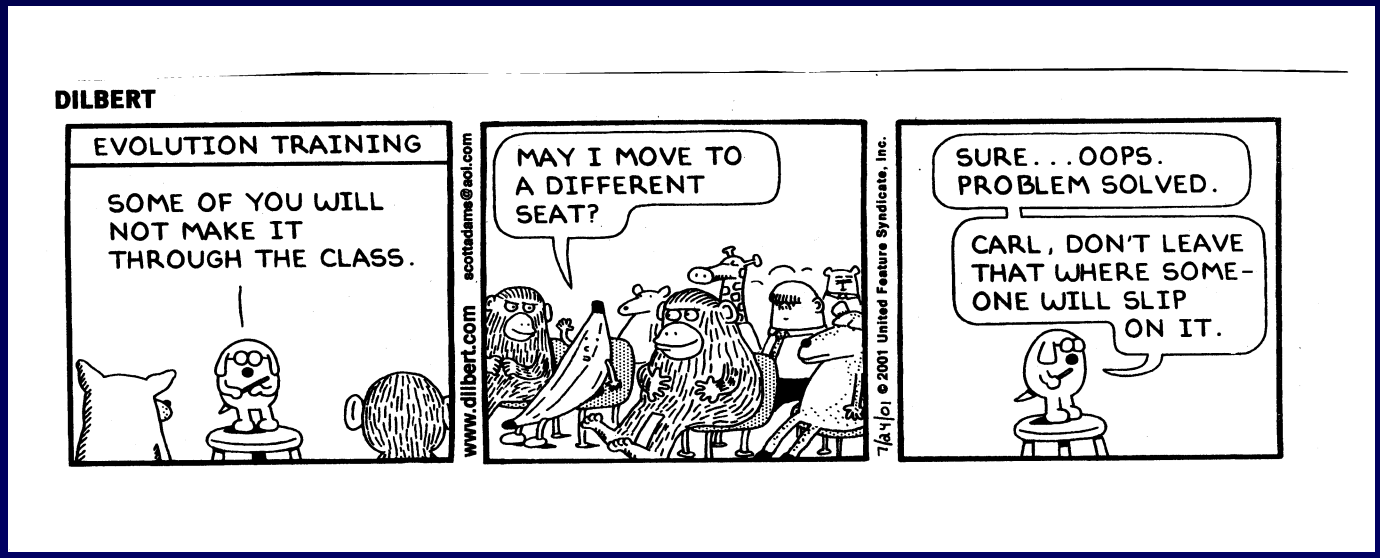
What can I learn from you?

Planners are doing very well
What is the role for ERDC?

What can I add to this course?

Sit down
Strap in
Hold on

Course Warning !


DILBERT
EVOLUTION TRAINING
SOME OF YOU WILL NOT MAKE IT THROUGH THE CLASS.
MAY I MOVE TO A DIFFERENT SEAT?
SURE...OOPS. PROBLEM SOLVED.
CARL, DON'T LEAVE THAT WHERE SOMEONE WILL SLIP ON IT.
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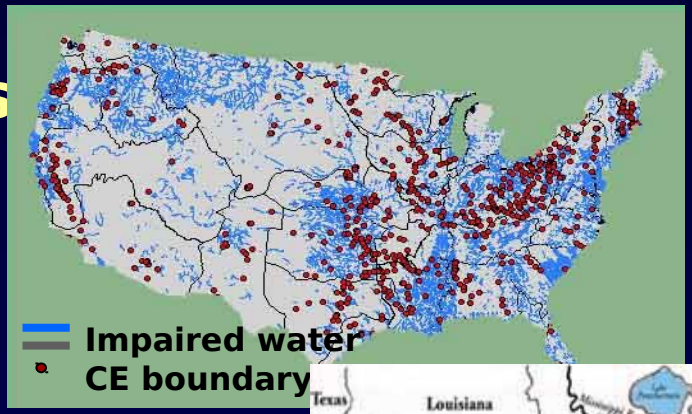
General Problem

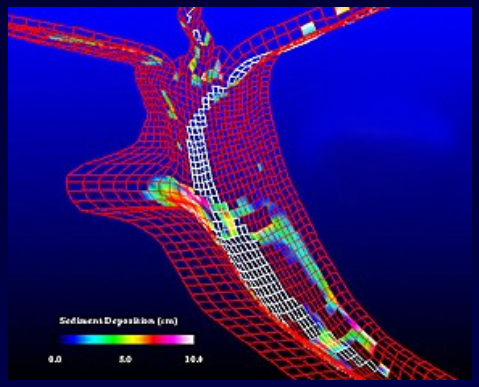
- The Nation's water resources are impacted by watershed and CE activities
- Technologies for system-wide assessments for sustainable management are not readily available

Specific Problems

- Impaired Water Resources
- Degraded Habitat
- Reduced Recreation
- Restricted Project Operati
- Loss of T&E Species Habitat
- Increased Mitigation
- Bad Publicity

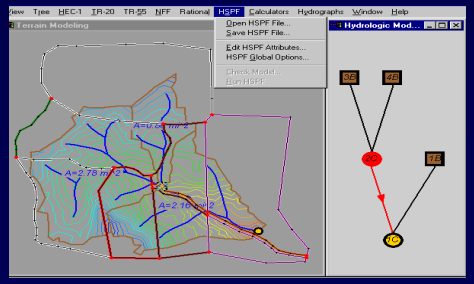


Needs



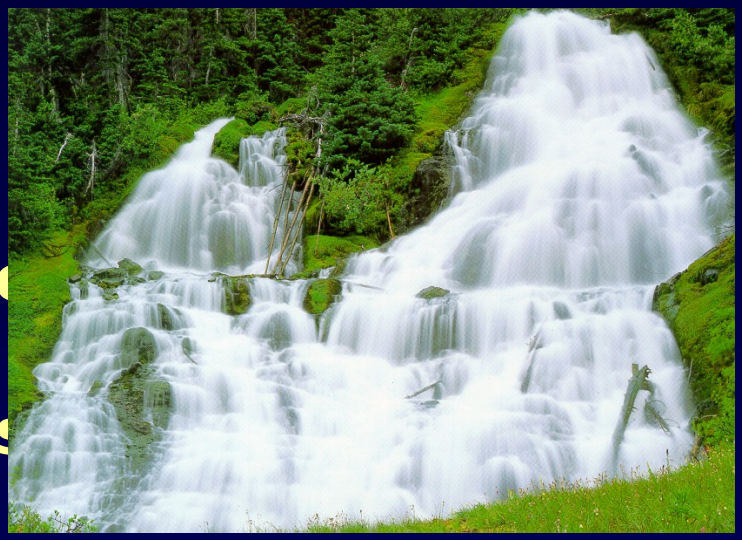
- **Improved Tools and Technologies**
- **Effective Applications**
- **Defendable Assessments**

(Identified from listening sessions and workshops)



- **Consistent with CE-EOP**
- **Environmental Sustainability**

Components for Assessing Watersheds (Course Outline)



Watershed Definitions

Aquatic/Hydrologic Feature

Social and Economic Needs

Assessment and Prediction Tools

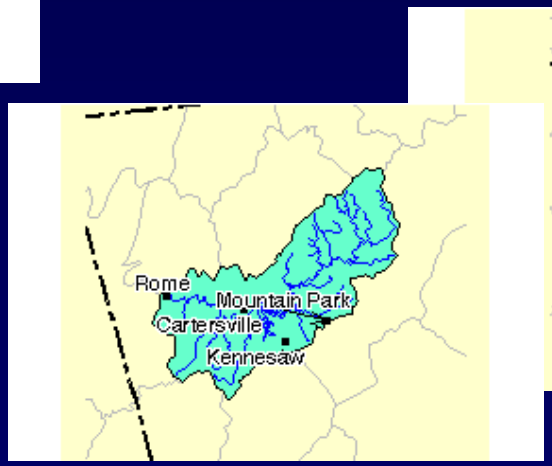
Implementation

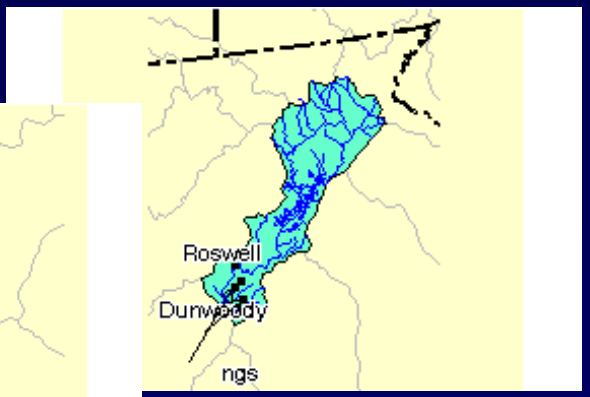
Sustainability and Adaptive Management

Watershed - Definitions

Watershed:
“The area drained by a river or river system” – *W*

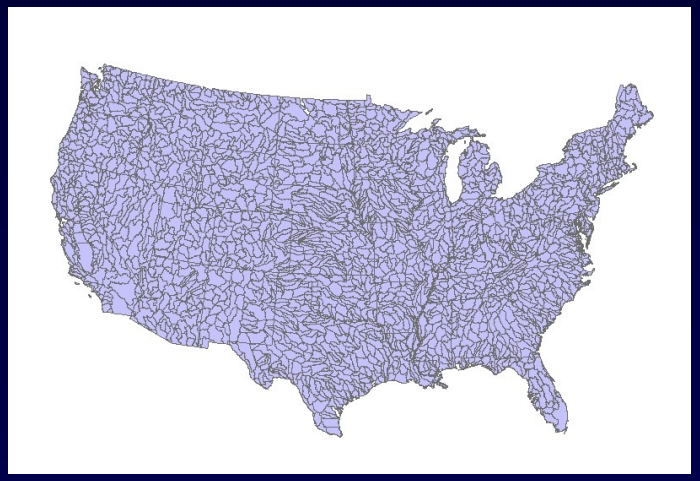
Basin:
“All the land drained by a river and its branches” – *Webster*



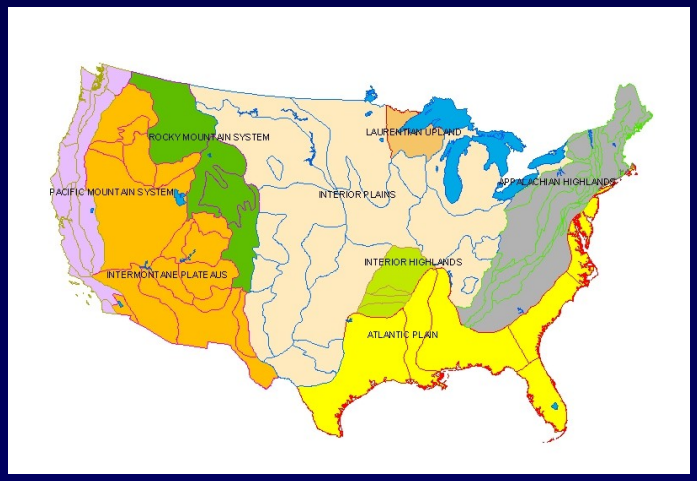


Watershed Boundaries

CE District Boundaries



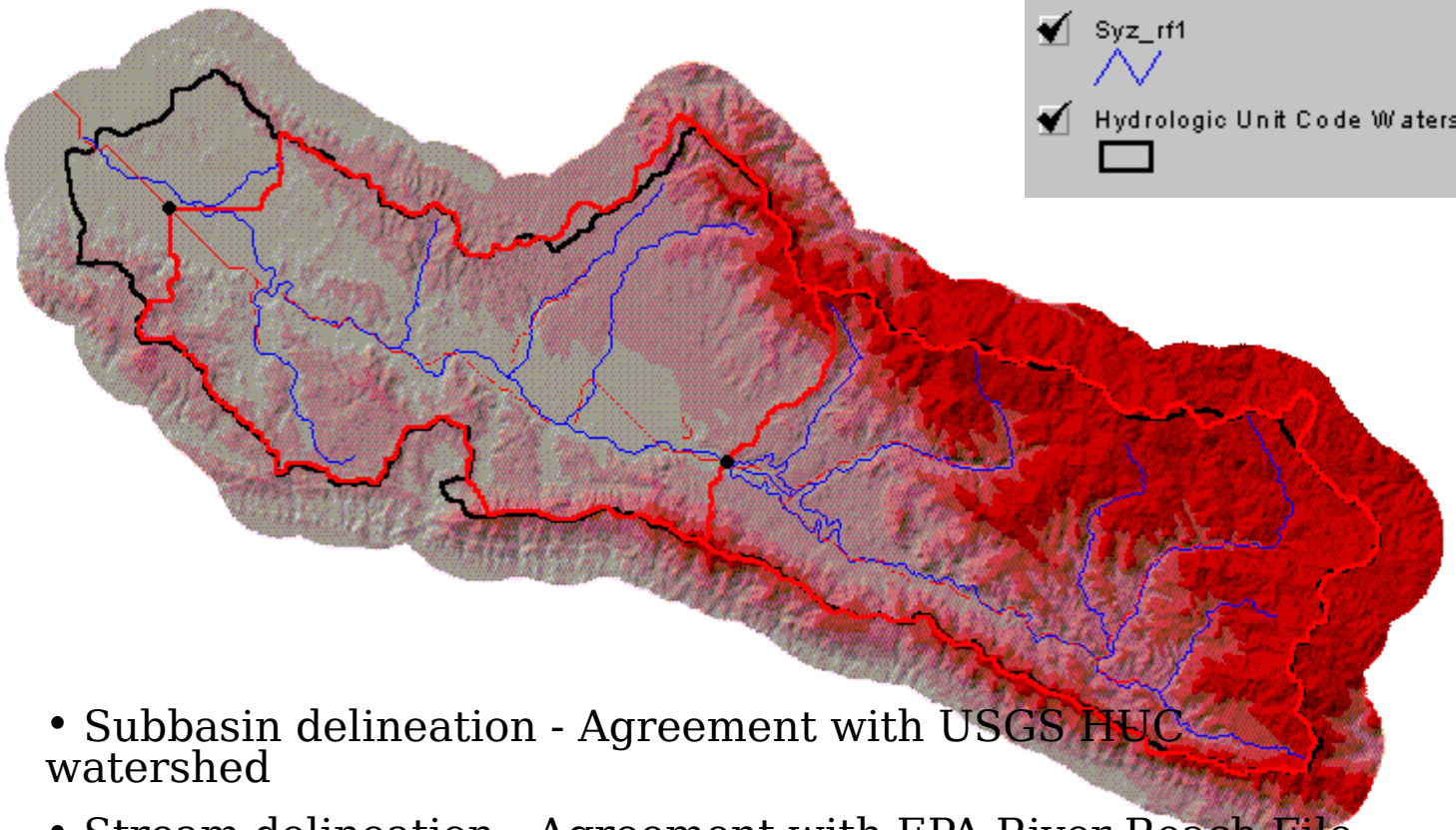
USGS Hydrologic Units



EPA Ecoregions

Political Boundaries

Streams and Subbasins



- Subbasin delineation - Agreement with USGS HUC watershed
- Stream delineation - Agreement with EPA River Reach File
- Tributary drainage areas at gages agree with published data

Watershed Features

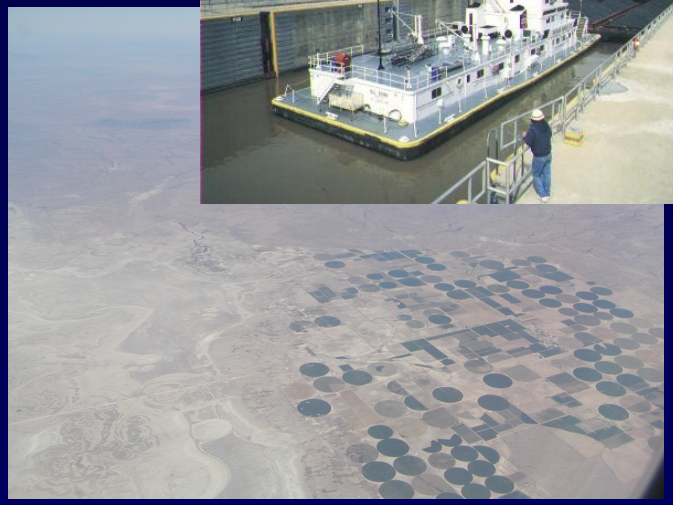
Landscape:
"An area composed of a mosaic of interacting ecosystems, or habitat patches" – *EPA SAB, 2002*

Watershed Characteristics

Essential Ecological Attributes *EPA SAB, 2002*	Aquatic Ecosystem Drivers *ESA Report, 200*
1. Landscape condition	*
2. Biotic condition	Biotic assemblage
3. Chemical and physical char.	Sediment and organic input Chemical and nutrie
4. Ecological Processes	Biotic assemblage
5. Hydrology and morphology	Flow regime
6. Natural disturbance regimes	*

What is missing?

Watershed Alterations



Unaltered → (Reference) ⇄ Human alteratio

Comparing Pre- & Post-project Hydrographs

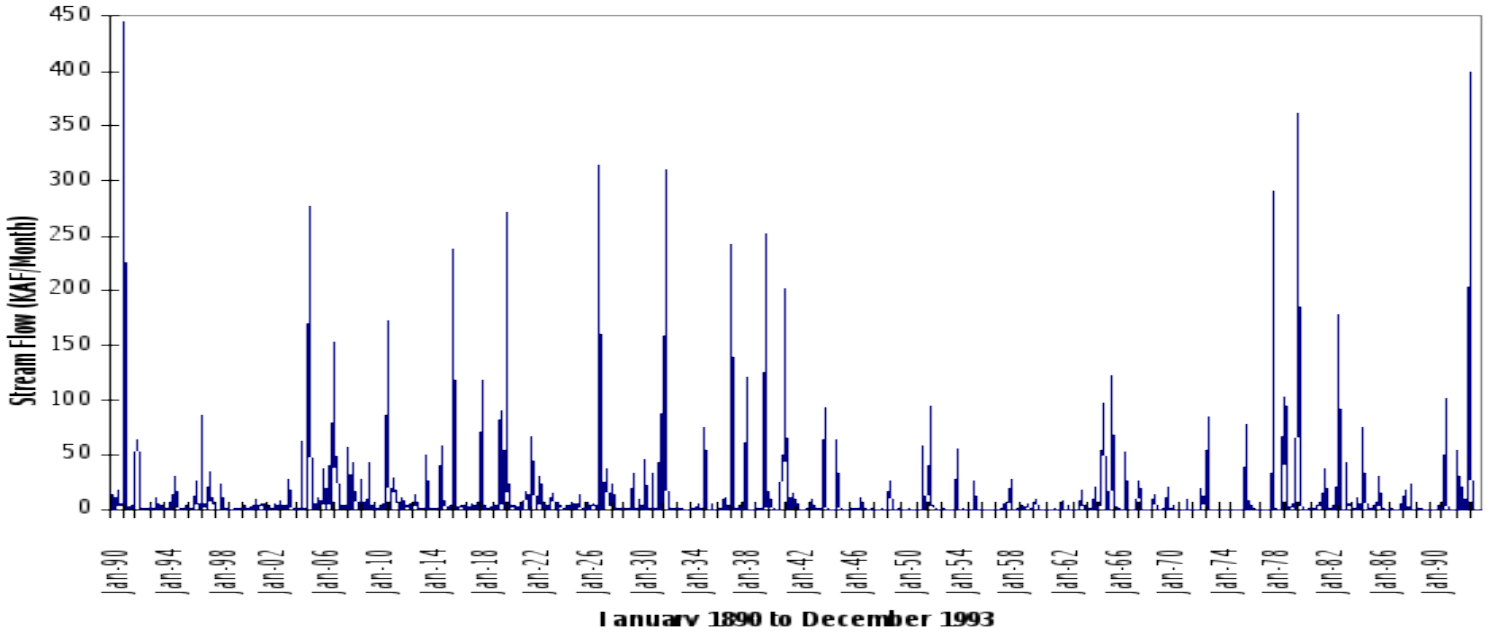


Figure 3.1 Historic (Pre-Dam) Stream Flows

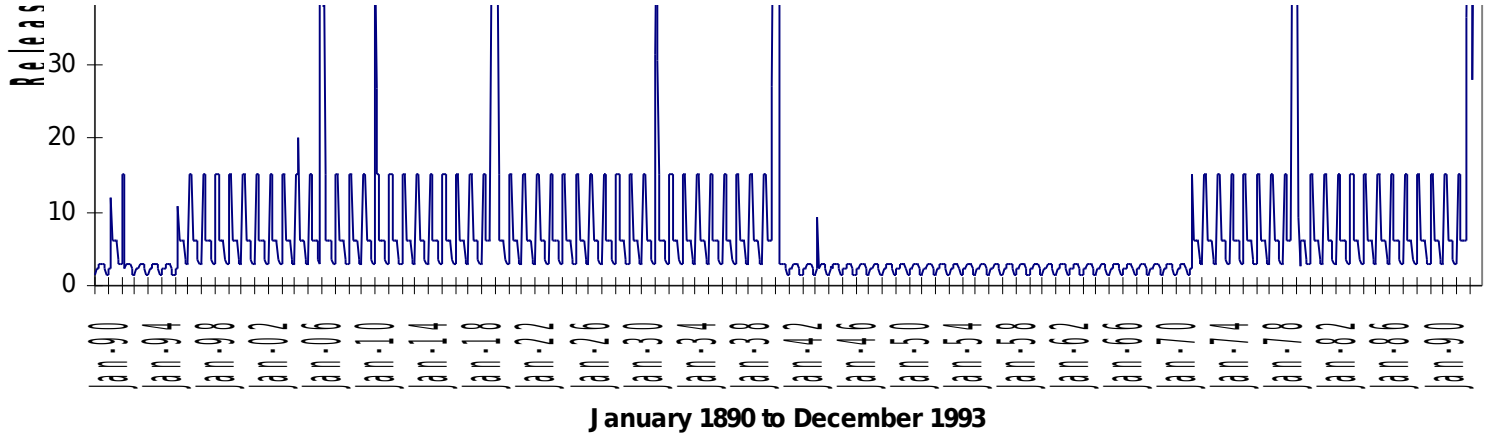


Figure 3.2 Monthly HEC-PRM Releases Based Strictly on Riparian Penalty Functions

What's the Point

Watershed assessments deal with issues of scale and complexity but there are logical, conceptual frameworks for developing watershed management plans.

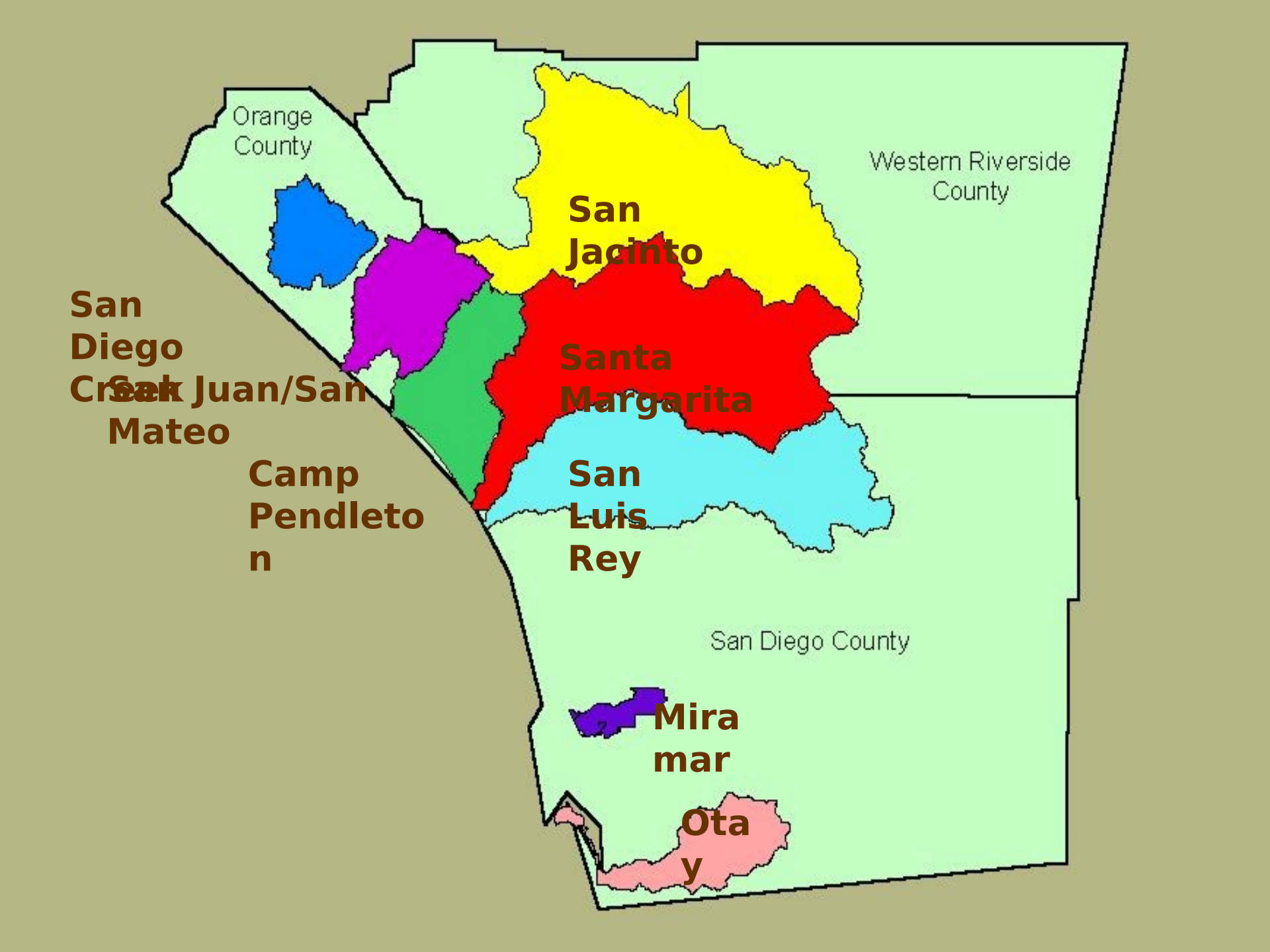
Geospatial Assessment

Watershed-Scale Indices of Wetland Integrity (WIWI)

Dan Smith, EL

Barb Kleiss, EL

SPL - Regulatory


Orange County
Western Riverside County
San Jacinto
San Diego Creek
San Juan/San Mateo
Santa Margarita
Camp Pendleton
San Luis Rey
San Diego County
Miramar
Otay

Project Objectives - Delineation

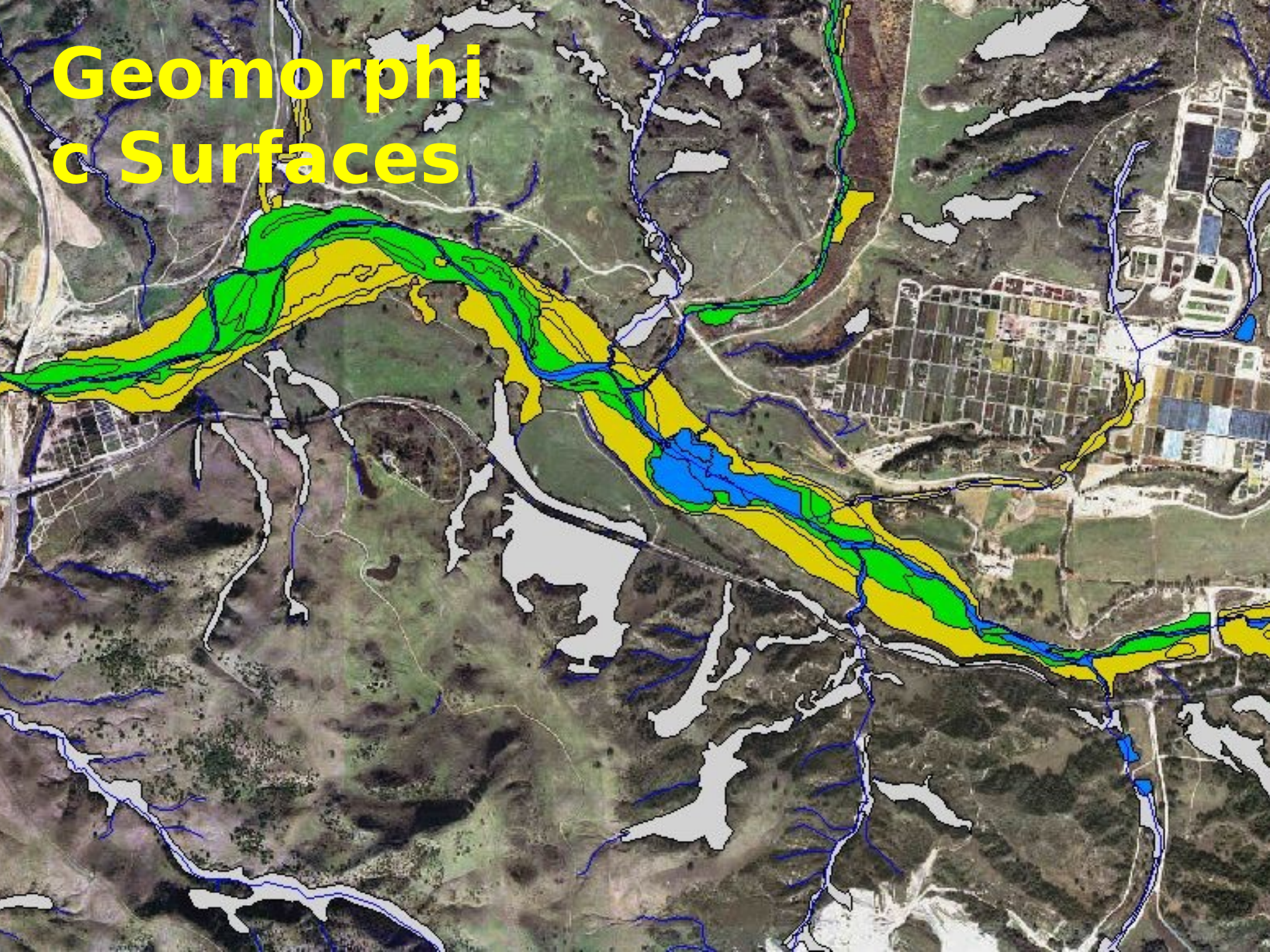
- Map non-wetland waters
- Map riparian ecosystems using geomorphic surface and vegetation communities
- Correlate hydrology, soils, and hydrophytic vegetation to geomorphic surfaces
- Develop ratings for riparian ecosystems that define the likelihood of WoUS occurring

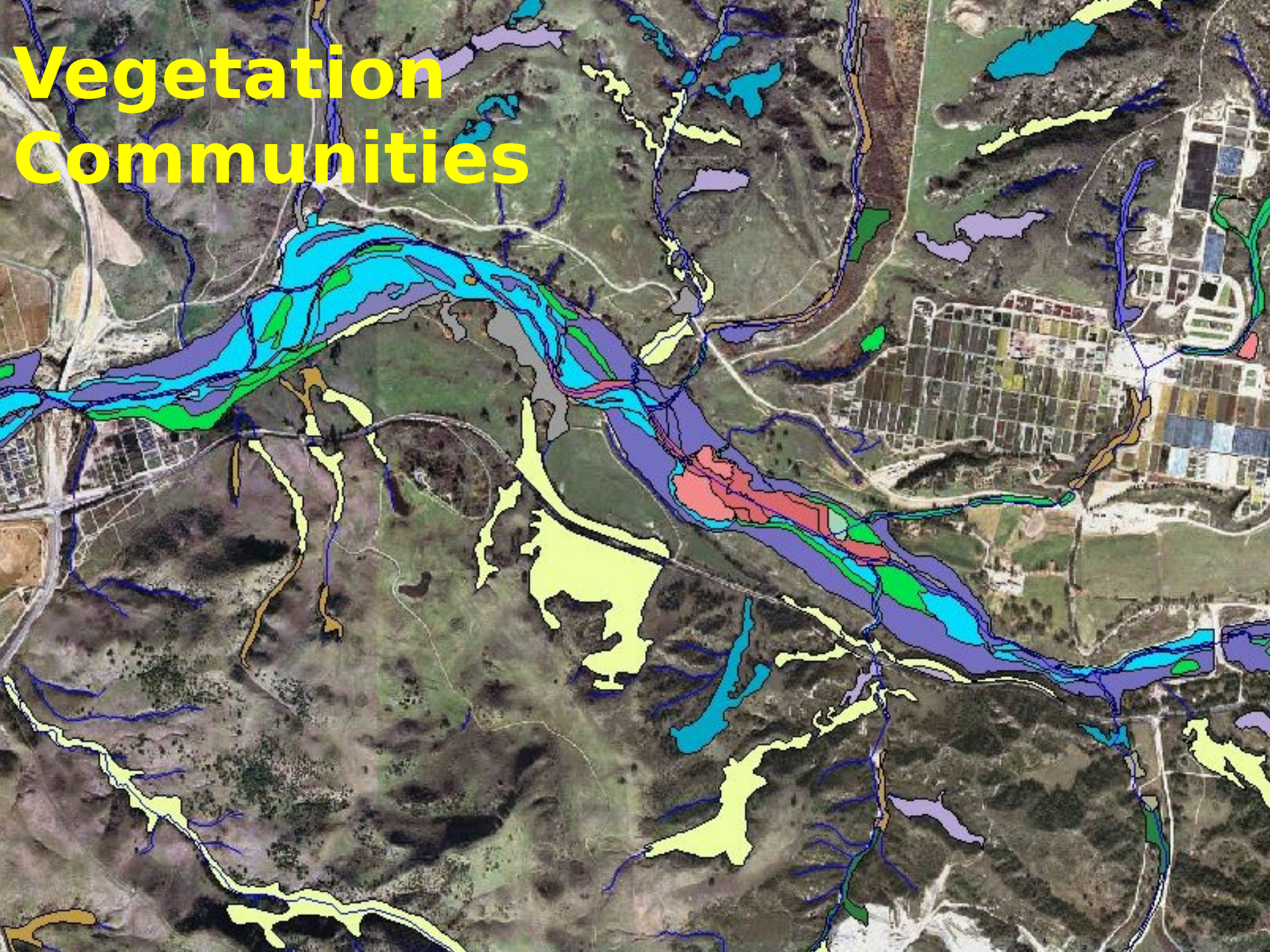
Approach

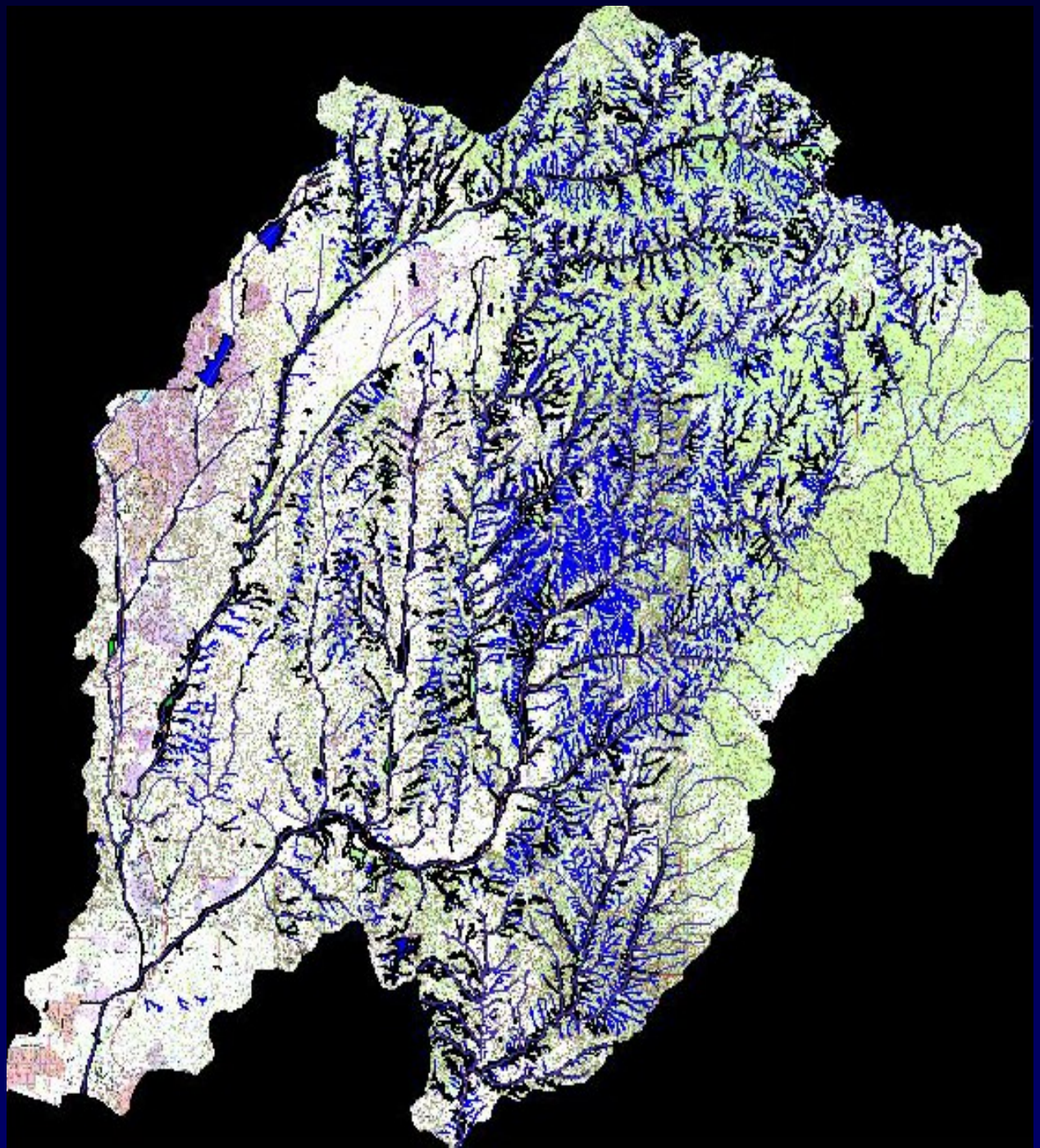
- **Indicator Scores and Indices**
  - **Indicator metric values were converted to a score based on an ordinal scale relationship between indicators and assessment endpoints established using field observation and judgment**
  - **Selected indicator scores were summed to give hydrologic, water quality and habitat integrity indices**

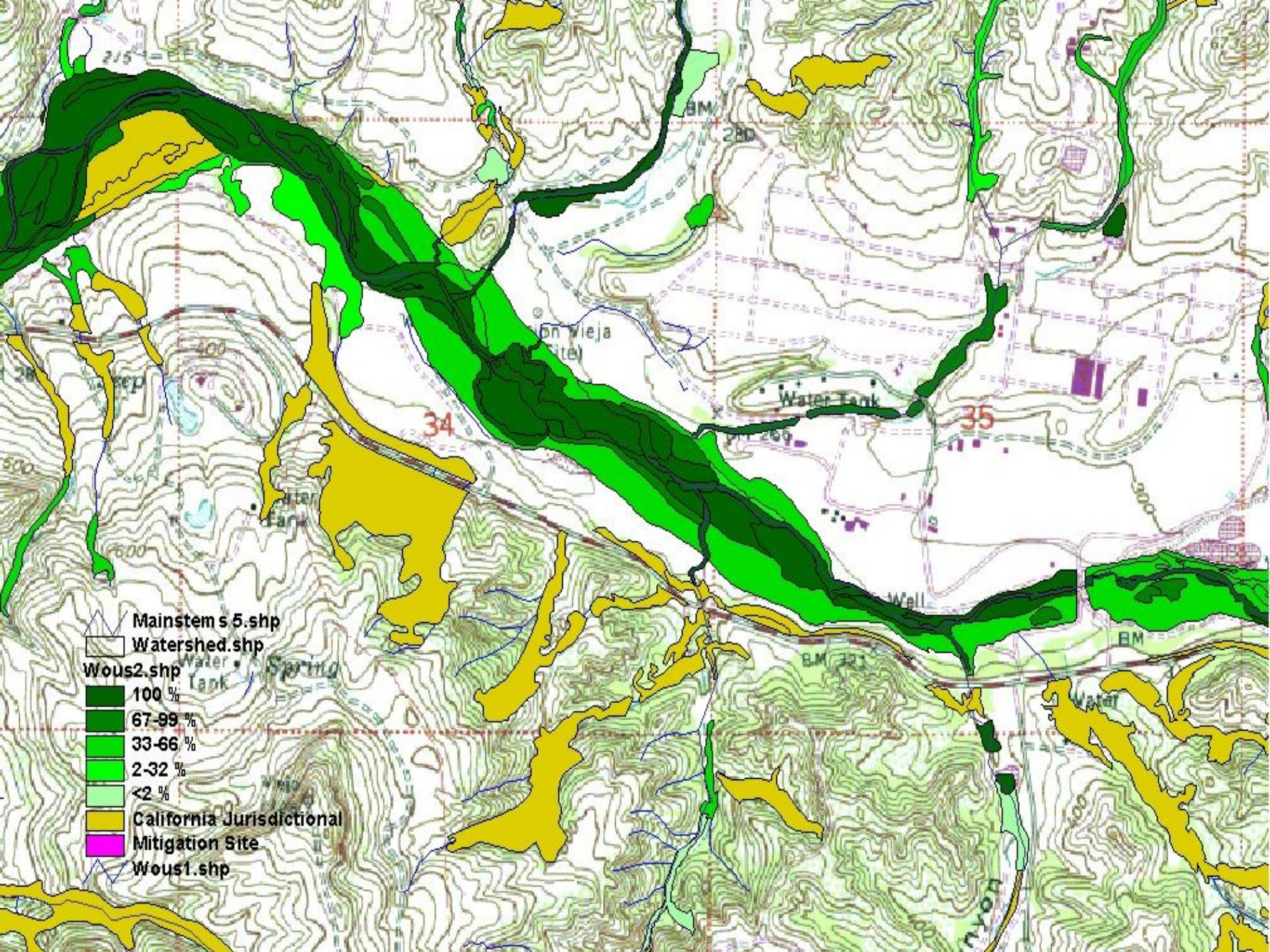
Indicator Metric Value Range	Score
<5% of main stem channel disconnected from the floodplain	5
>5 and <15% of main stem channel disconnected from the floodplain	4
>15 and <30% of main stem channel disconnected from the floodplain	3
>30 and <50% of main stem channel disconnected from the floodplain	2

Geomorphic Surfaces




Vegetation
Communities




Mainstems 5.shp
Watershed.shp
Wous2.shp
100 %
67-99 %
33-66 %
2-32 %
<2 %
California Jurisdictional
Mitigation Site
Wous1.shp
34
35
Water Tank
Spring
Well
BM
Water

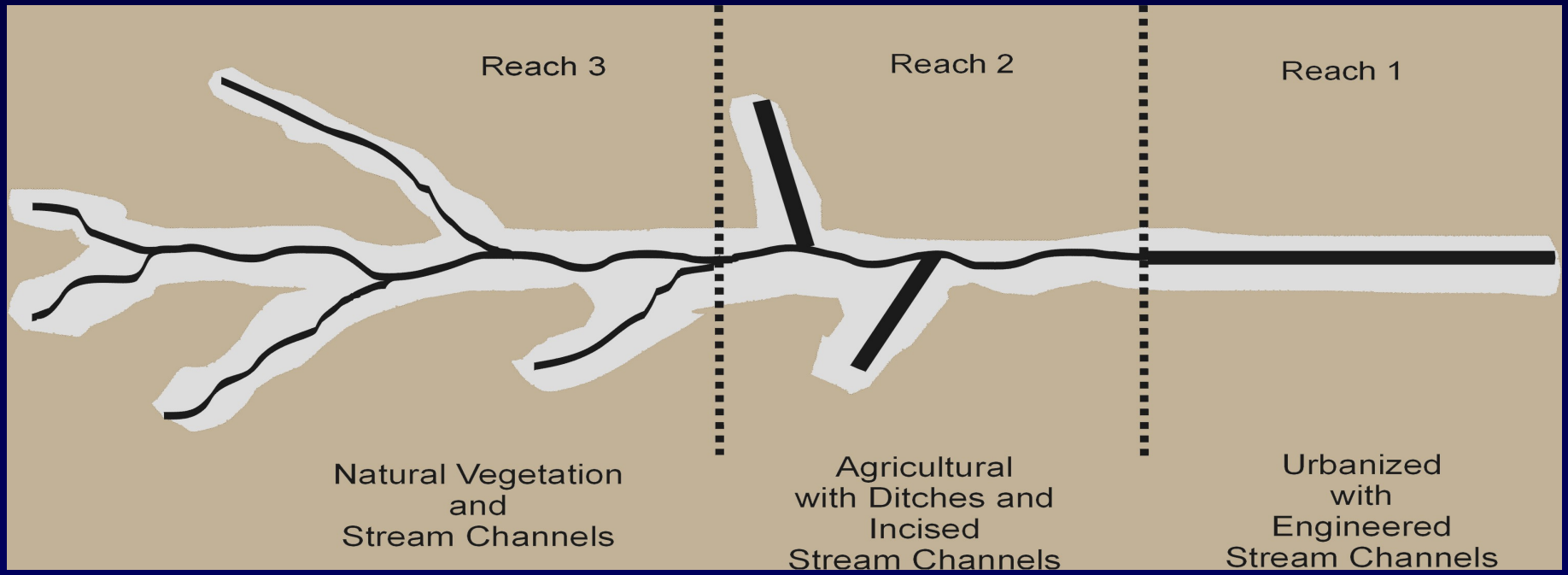
Project Objectives - Assessment

- Conduct a multiple spatial scale baseline assessment of riparian ecosystem integrity
- Simulate and assess riparian ecosystem integrity under alternative development scenarios and compare to the baseline assessment
- Recommend actions to avoid and minimize project specific and cumulative impacts to riparian ecosystems
- Develop a wetland reserve system in conjunction with a watershed restoration program

Assessment Approach

- Define riparian ecosystem assessment units
- Select riparian ecosystem integrity endpoints
- Identify indicators for assessing endpoints
- Characterize and assess riparian assessment units
- Combine indicators into indices representing endpoints, and summarize results graphically and spatially
- Simulate and assess alternative development scenarios
- Compare results to baseline assessment
- Develop “environmental constraints” map and recommendations to avoid and minimize project specific and cumulative impacts

Riparian Reaches



Assessment Endpoints

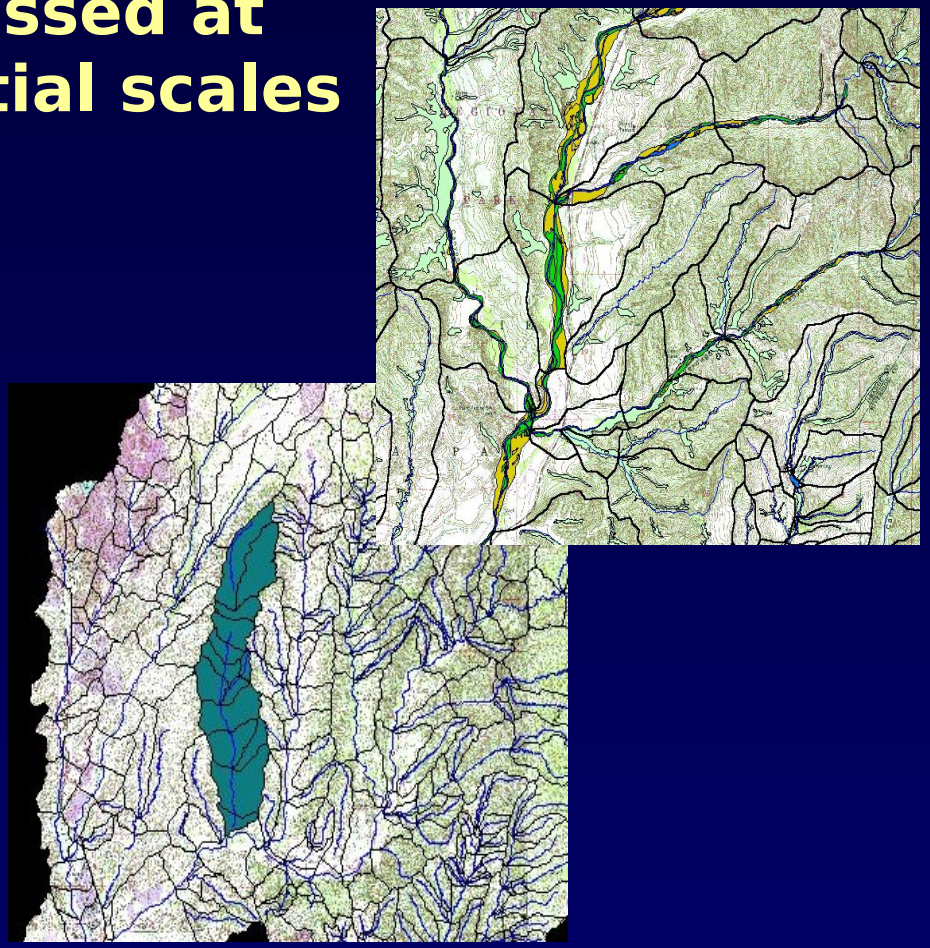
- Three quantities of interest or “assessment endpoints” were selected including…
  - Hydrologic Integrity
  - Water Quality Integrity
  - Habitat Integrity
- The selection of these endpoints follows directly from the CWA mandate to “…restore and maintain the chemical, physical, and biological integrity of the Nation’s waters”

Assessment Indicators

- Once endpoints were defined, indicators were selected to assess the endpoints
- Indicators are characteristics of the riparian ecosystem, the surrounding upland, and drainage basin that are related to the assessment endpoint
- The use of indicators in biological/ecological assessments is common (i.e., HEP, IBI, HGM Approach)
- The use of indicators was dictated by the large project area, abstract nature of assessment endpoints, and lack of data on which to base more quantitative metrics

Spatial Scale of Indicators

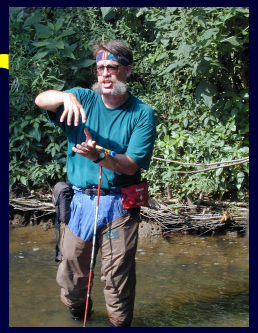
- Indictors were assessed at three different spatial scales
  - Riparian Reach
  - Local Drainage
  - Drainage Basin



Hydrologic Indicators

- Hydrologic indicators included:
  - Altered Hydraulic Conveyance
  - Surface Water Retention in lakes, reservoirs, and ponds
  - Perennialized Stream Flow
  - Hydrologic Interaction between stream channel and floodplain
  - Import, Export, and Diversion of Surface Water

Water Quality Indicator



- Water quality indicators included:
  - Land Use/Land Cover - Nutrient Increase
  - Land Use/Land Cover – Pesticide Increase
  - Land Use/Land Cover – Hydrocarbon Increase
  - Land Use/Land Cover – Sediment Increase
  - Land Use/Land Cover – Upland Buffer
  - Land Use/Land Cover – Riparian/Upland Boundary
  - Altered Hydraulic Conveyance – Reach Scale
  - Altered Hydraulic Conveyance - DB Scale
  - Surface Water Retention
  - Perennialized Stream Flow
  - Import, Export, or Diversion of Surface Water
  - Floodplain Interaction
  - Sediment Regime
  - Extent of Riparian Plant Communities

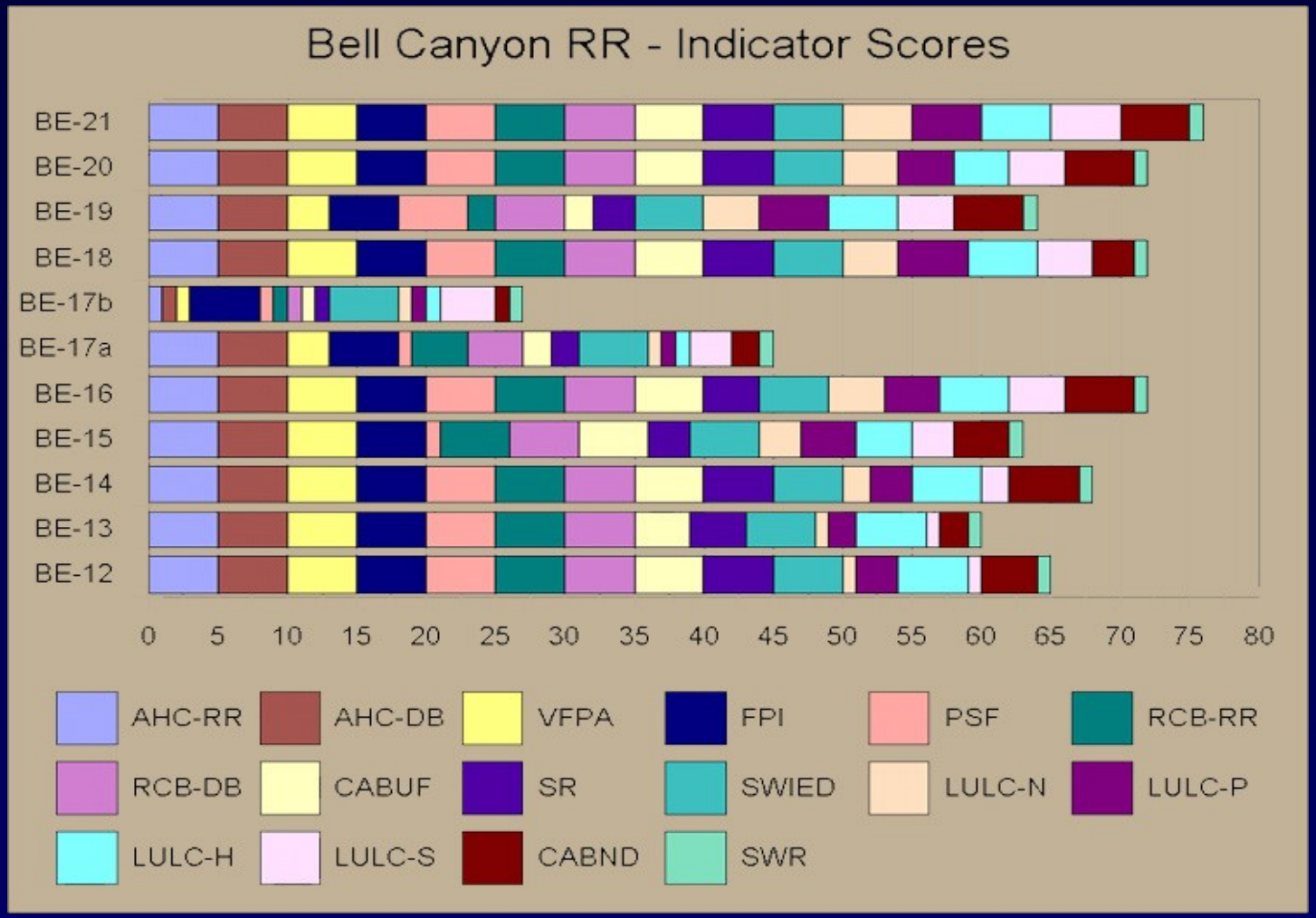
Habitat Indicators

- Extent of Riparian Plant Communities
- Extent of Exotic Plant Species
- Riparian Corridor Continuity – Riparian Reach Scale
- Riparian Corridor Continuity – Drainage Basin Scale
- Land Use / Land Cover – Riparian/Upland Boundary
- Land Use / Land Cover – Upland Buffer

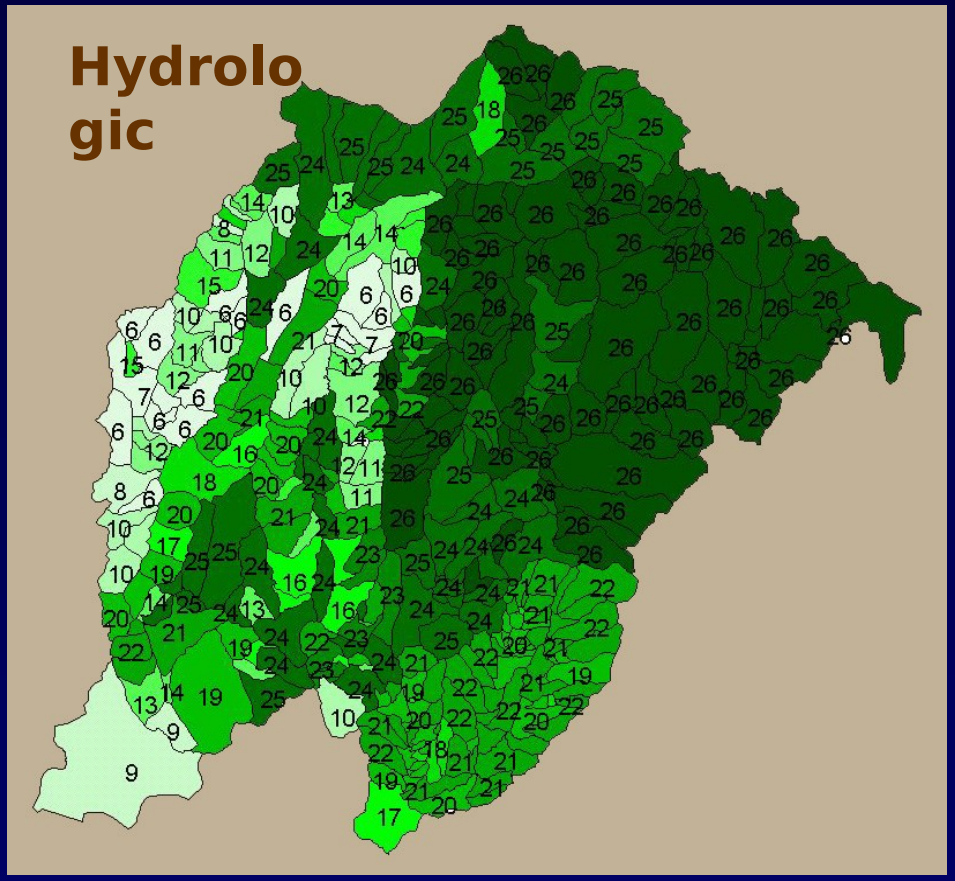
Reference Condition

- Assessment of ecosystem integrity requires a standard of comparison, or “reference condition” be established for scaling indicators
- Ideally, it is absolute and not a relative standard of comparison
  - Ease of establishing and interpreting the standard
  - Comparability across wetland types and regions
- “Culturally unaltered” was selected as reference condition
- This reference condition represents the physical, chemical, and biological conditions under which riparian ecosystems achieve and sustain a high level of integrity,and implies the conditions that existed prior to grazing, agriculture, water management, wildfire suppression, and urban development

Graphical Summary of Results

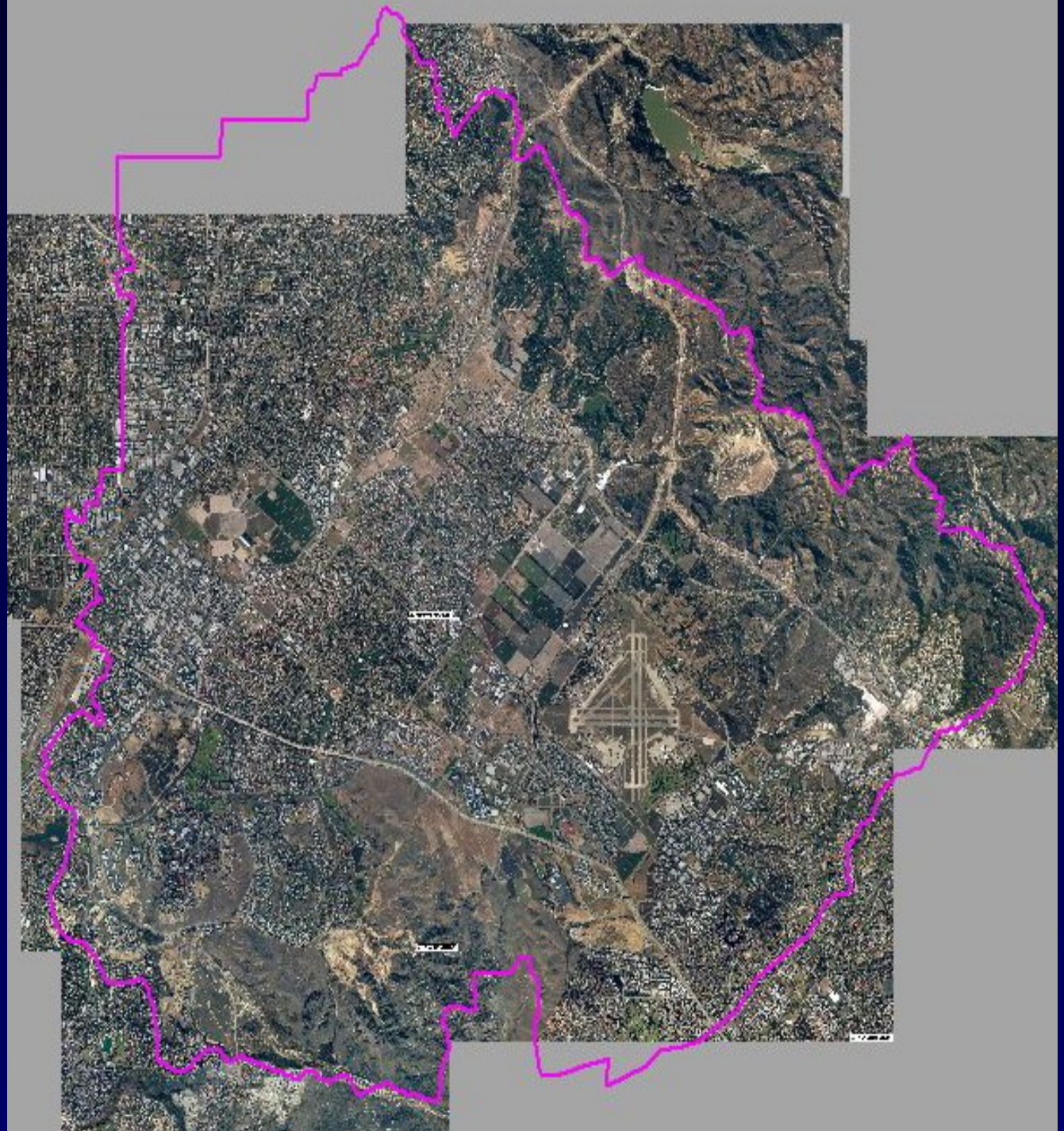


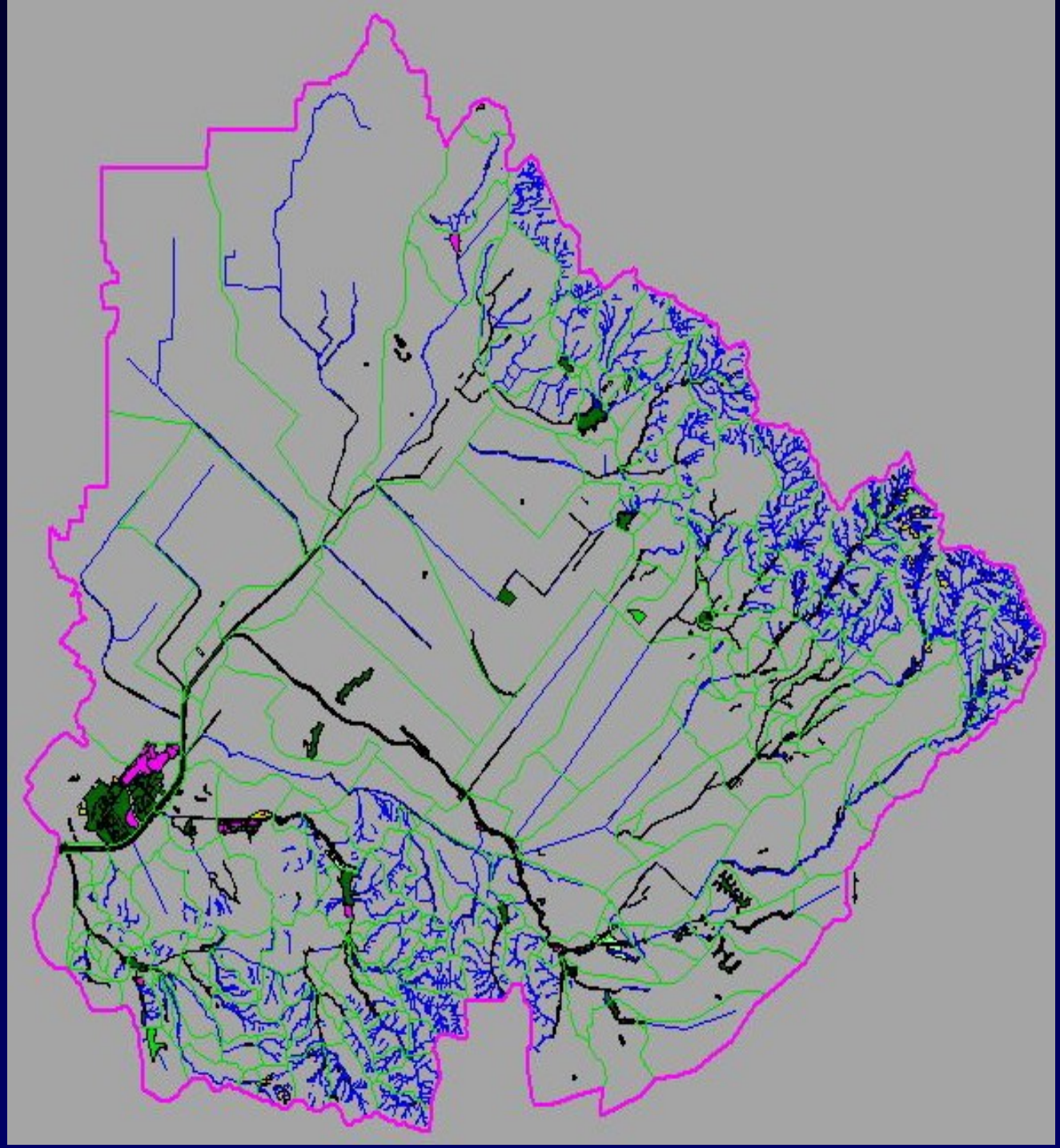
Spatial Display of Integrity Indices



Alternatives Analysis

- Objectives
  - Establish general and programmatic permits for activities regulated under the 404 Program in target watersheds
  - Establish protection and management areas in target watersheds in coordination with the Natural Community Conservation Plan (NCCP) and Habitat Conservation Plan (HCP)

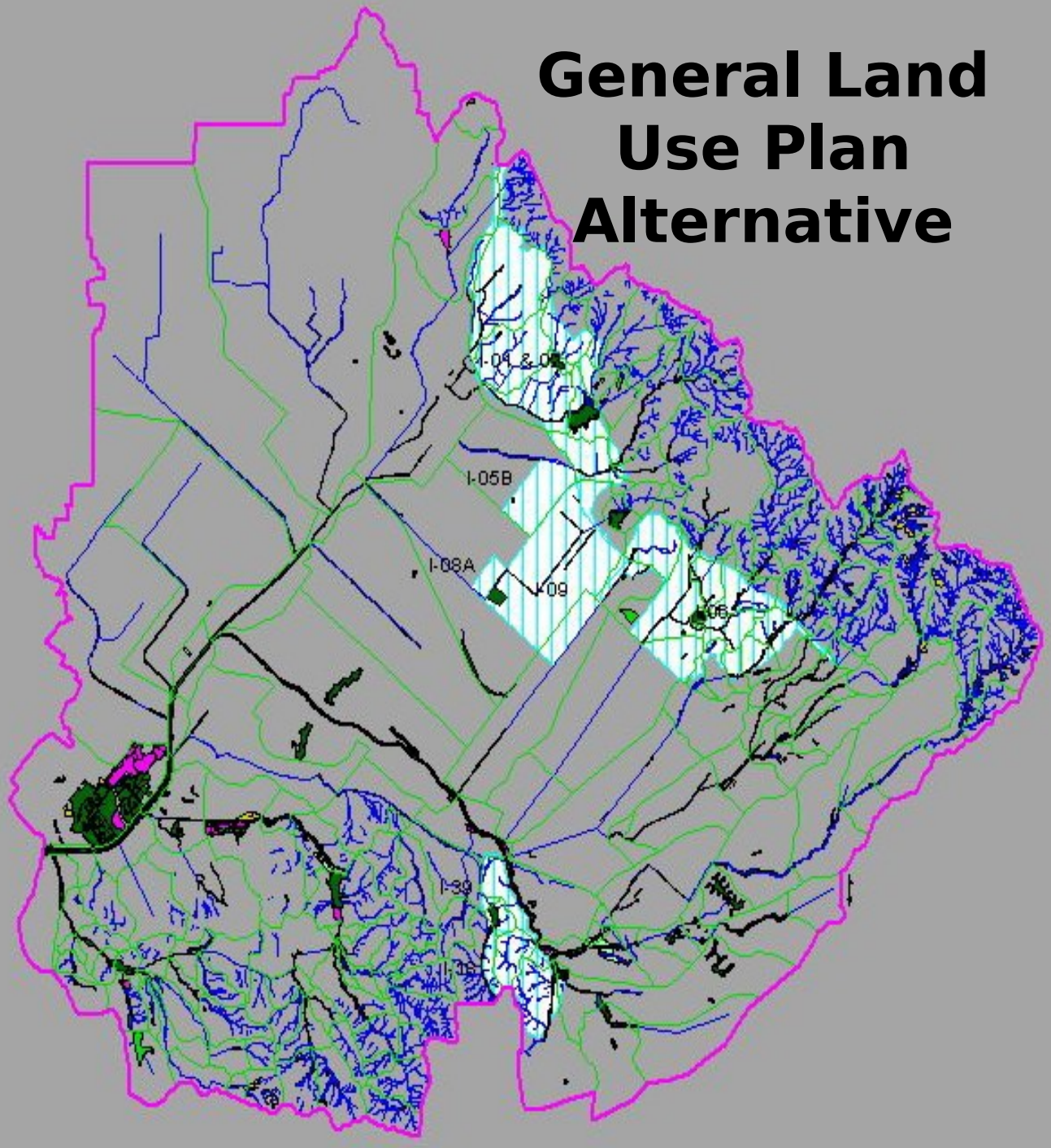




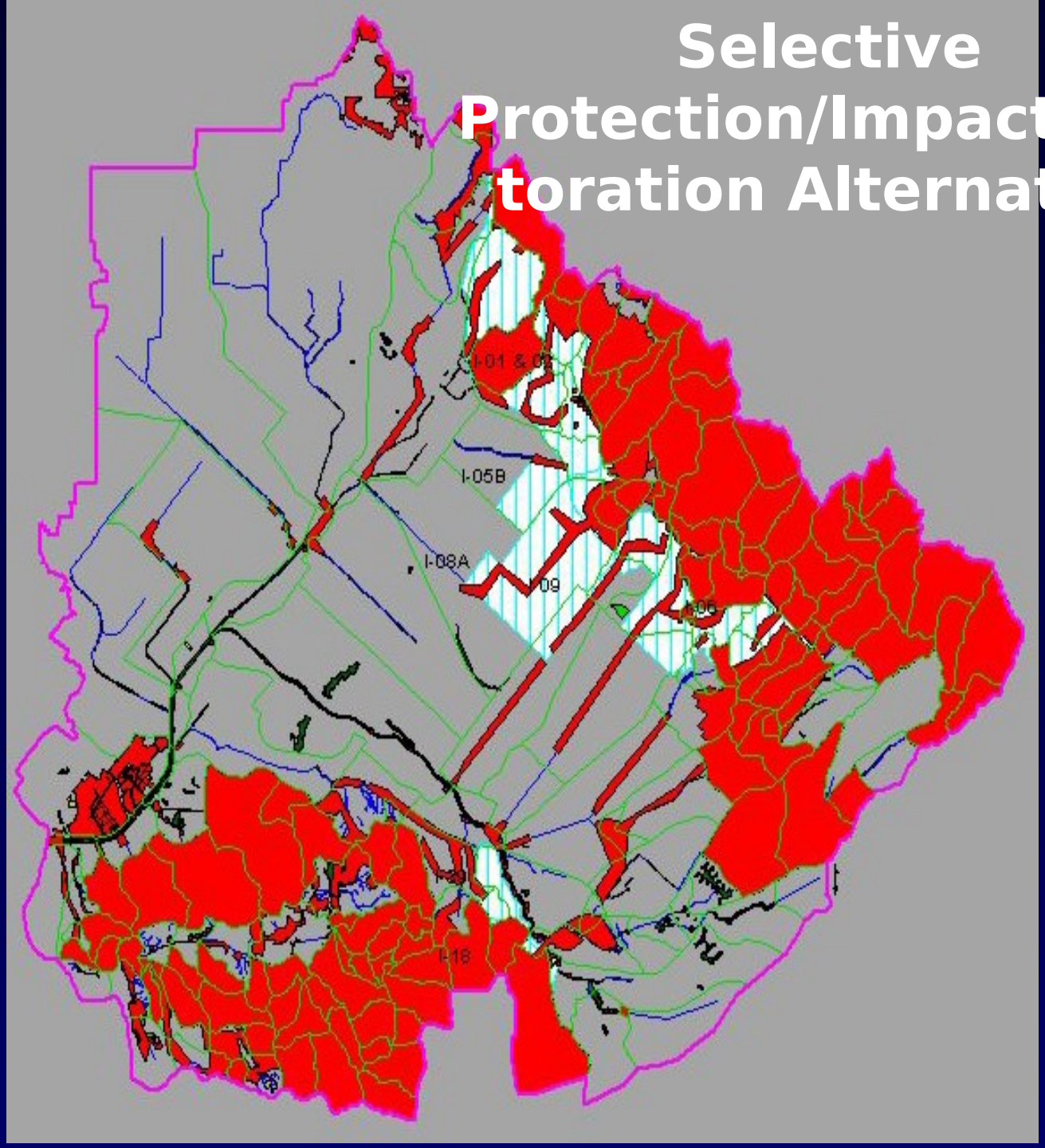
Proposed Alternatives

- Alternative 1 - No action
- Alternative 2 - No fill
- Alternative 3 – Existing General Land Use Plan
- Alternative 4 - Selective protection/impact/restoration
  - Riparian reaches with a medium to high level of hydrologic, water quality, and habitat integrity in the context of the local drainage
  - Areas currently occupied by low integrity riparian ecosystems and/or non-riparian and non-developed with the potential through restoration to serve as corridors connecting existing patches of riparian ecosystem
  - Aquatic resources and associated upland habitat currently supporting federally and state listed and sensitive species
  - Aquatic resources designated as Critical Habitat
- Management, conservation, or research reserve areas

General Land Use Plan Alternative



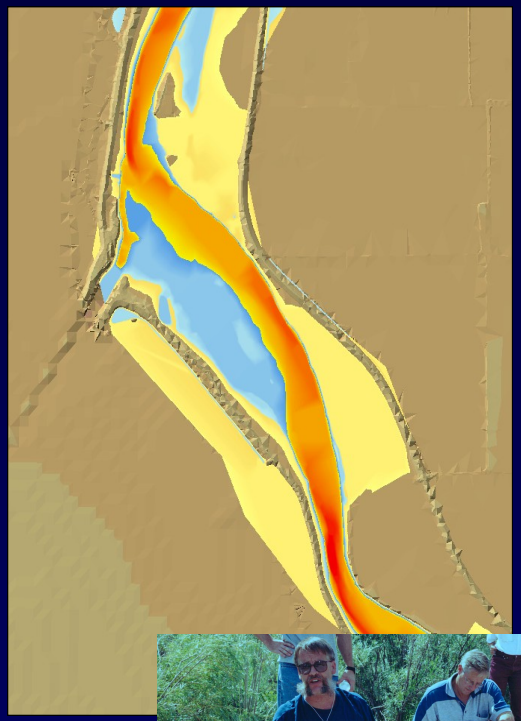
Selective Protection/Impact/Restoration Alternative



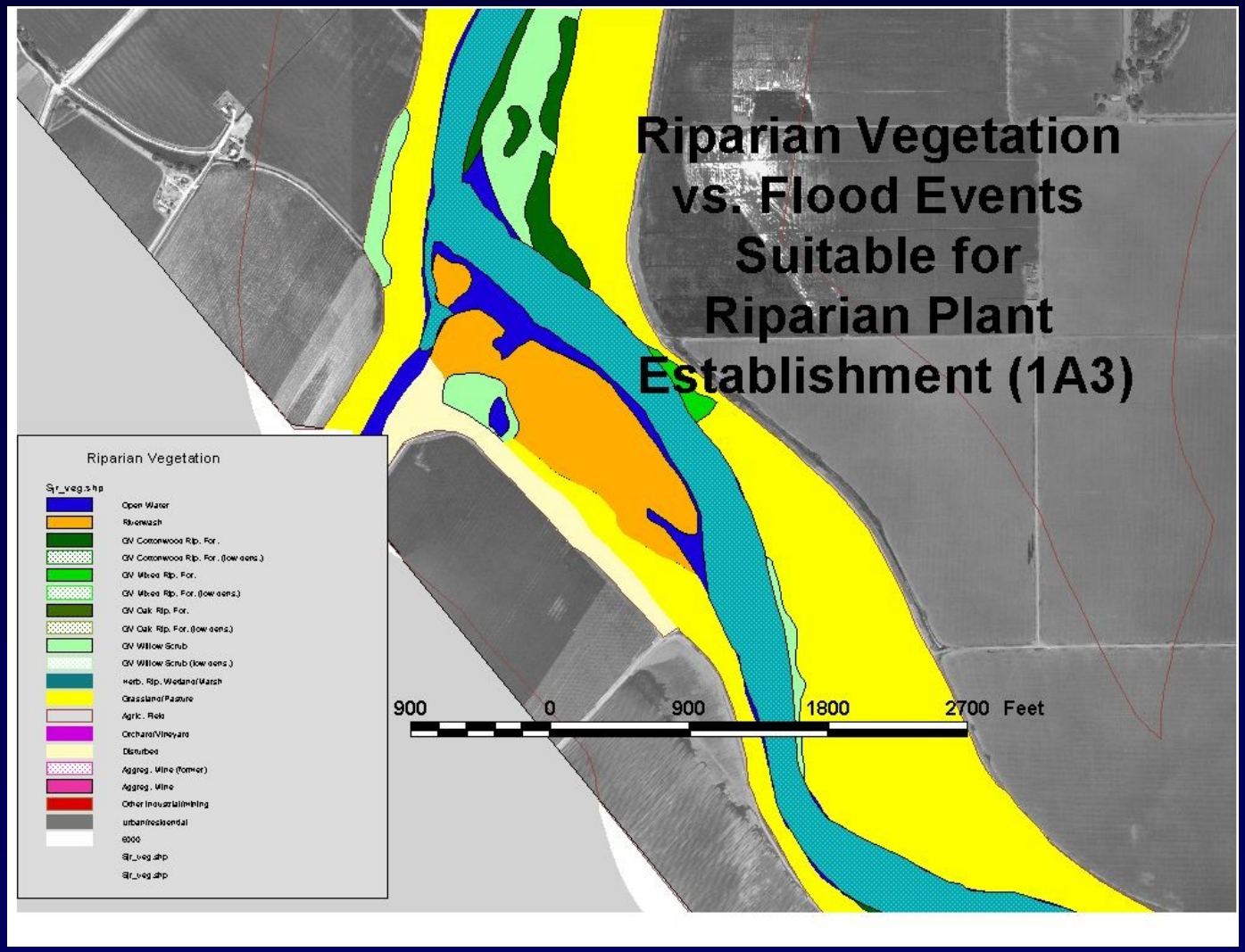
Most Plagiarized photo

HEC Tools

- HEC-HMS, HEC-ResSim, HEC-RAS, HEC-FIA, HEC-FDA, & HEC-EFM, & outside software
- CWMS
  - database of physical data
  - precipitation
  - streamflow
  - model parameters
  - spatially referenced maps and
  - displays
  - internet/web-sight links
- Watershed Analysis System
- Ecosystem Function Model



Ecosystem Functions Model

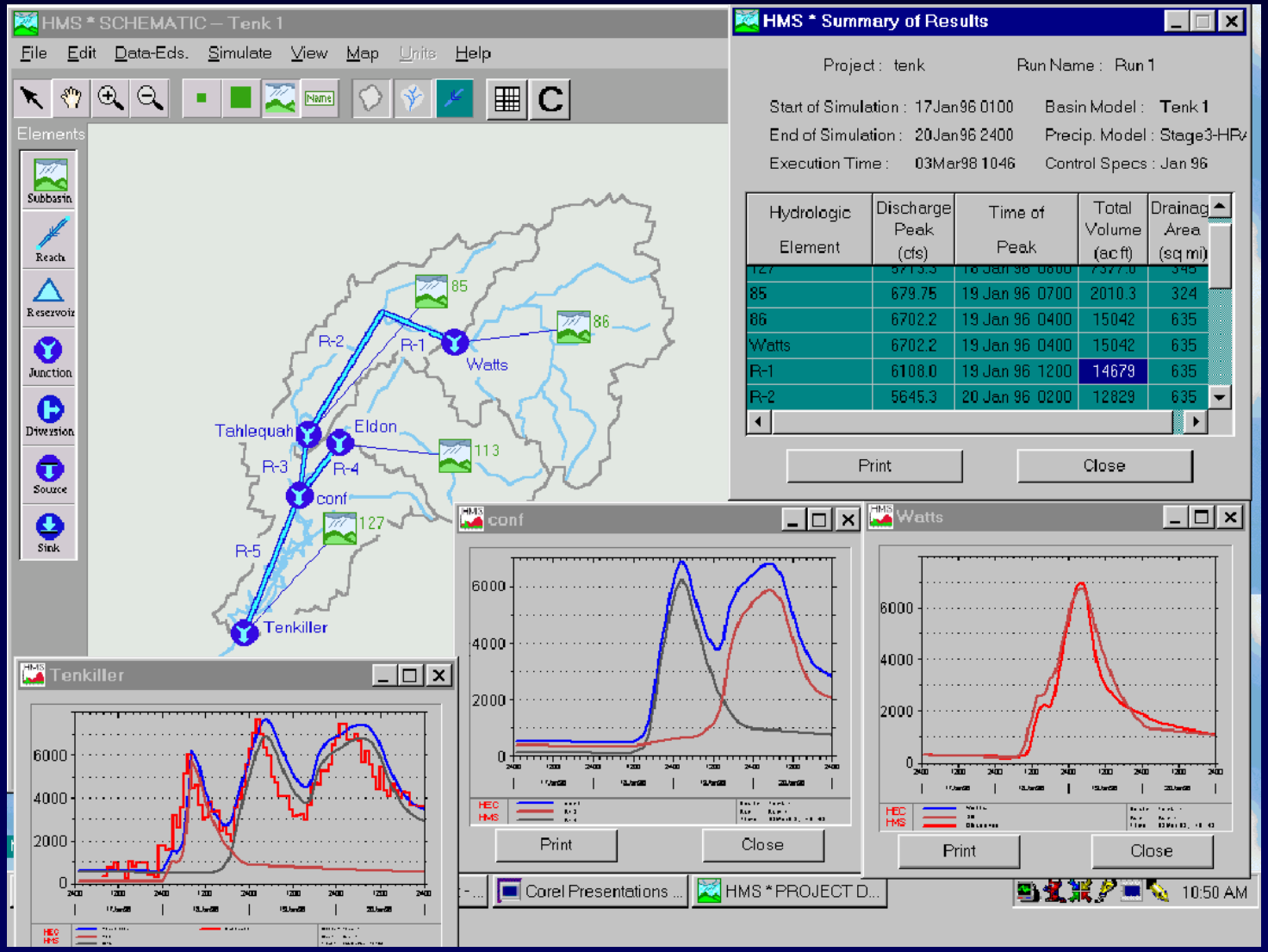


POC Chris Dunn – IWR/HEC

Using HEC-HMS for the Sacramento & San Joaquin River Basins Comprehensive Study

IWR/HEC

ntershed Analysis - Hydrologic Modeling Syste



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Empirically Based, Lumped Models

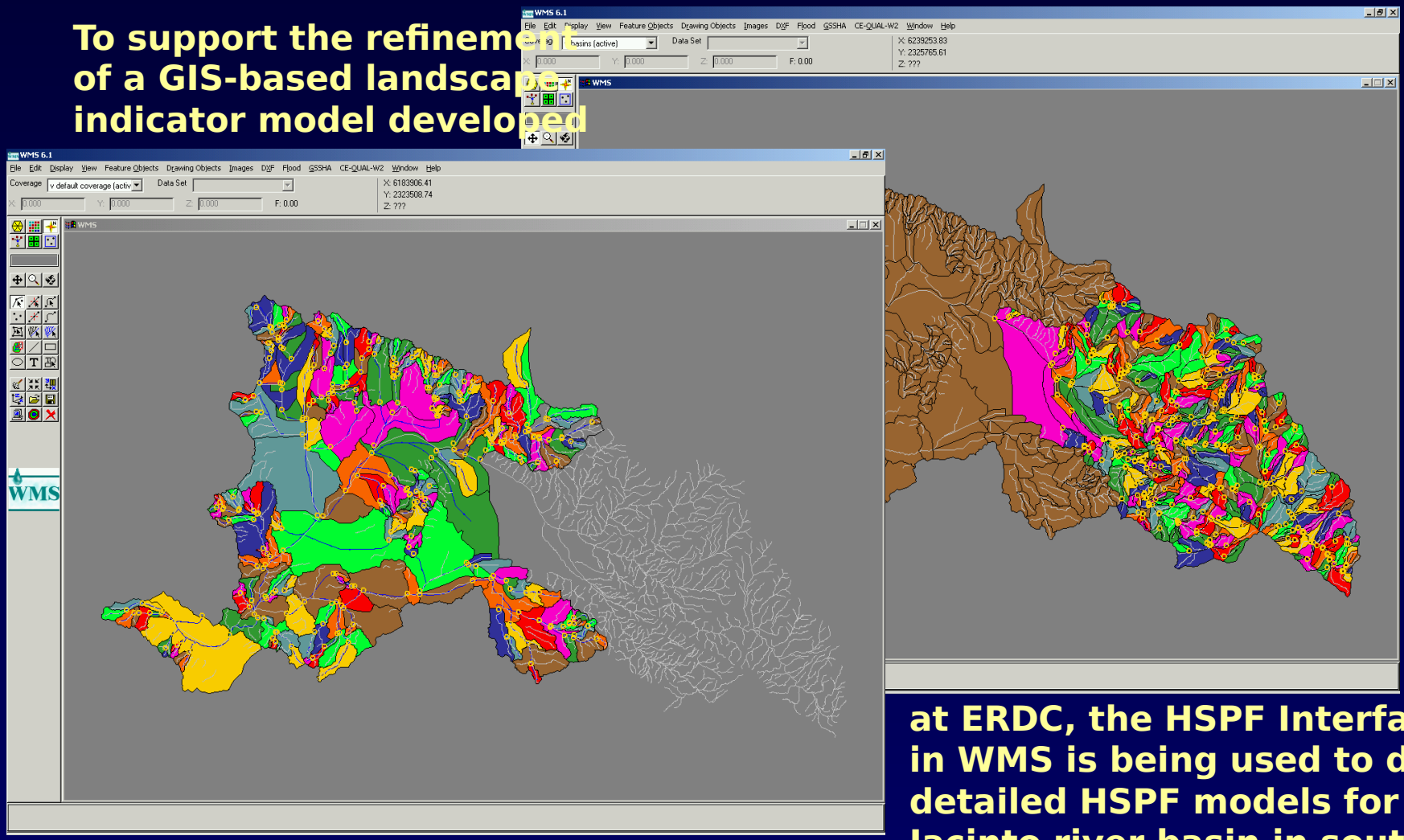
- Subdivide watersheds into smaller sub-watersheds.
- A single parameter value represents the entire sub-watershed.
- Empirical relationships relate flows to hydrologic inputs.

Empirically Based, Lump Models

- Advantages
  - easy to use
  - widely accepted
- Disadvantages
  - requires substantial calibration data
  - not useful outside the range of calibration
  - do not provide process information
- Examples
  - HEC-1, HEC HMS, HSPF, Rational Method

Lump Model Representation of Watershed

To support the refinem
of a GIS-based landsca
indicator model develo

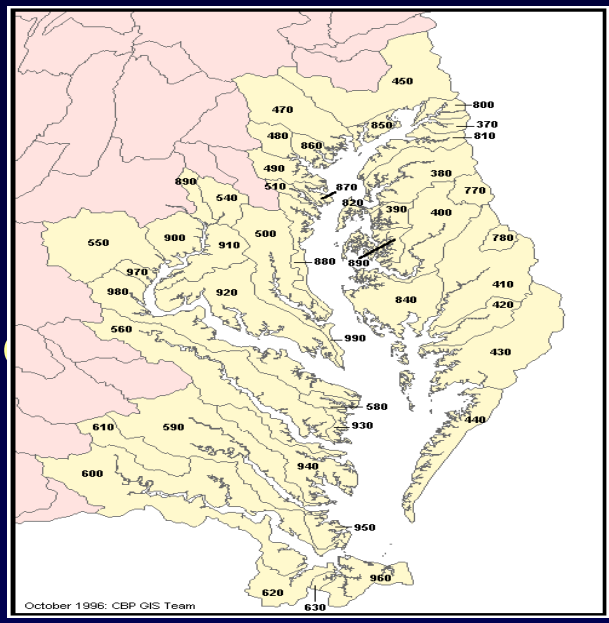

WMS 6.1
File Edit Display View Feature Objects Drawing Objects Images DXF Flood GSSHA CE-QUAL-W2 Window Help
Coverage
Data Set
WMS

at ERDC, the HSPF Interface in WMS is being used to devel detailed HSPF models for the Jacinto river basin in southern

Applicability

- Watersheds with extensive calibration data
- Analyze events within calibrated range
- Best applications are on large basins when the model can be continuously recalibrated

Hydrologic Simulation Program Fortran (HSPF)



- Continuous simulation model
- Natural and developed watersheds and water systems
- Land surface and subsurface hydrolo and quality processes
- Stream/lake hydraulics and water quality processes
- Time series data management and storage
- Time series data statistical analysis and operations
- Core watershed model in EPA BASINS and Army Corps WMS
- Development and maintenance activities sponsored by U.S. EPA (CEAM) and U.S. Geological Survey Office of Surface Water (HASS)

HSPF OPERATION MODULES

Application Modules

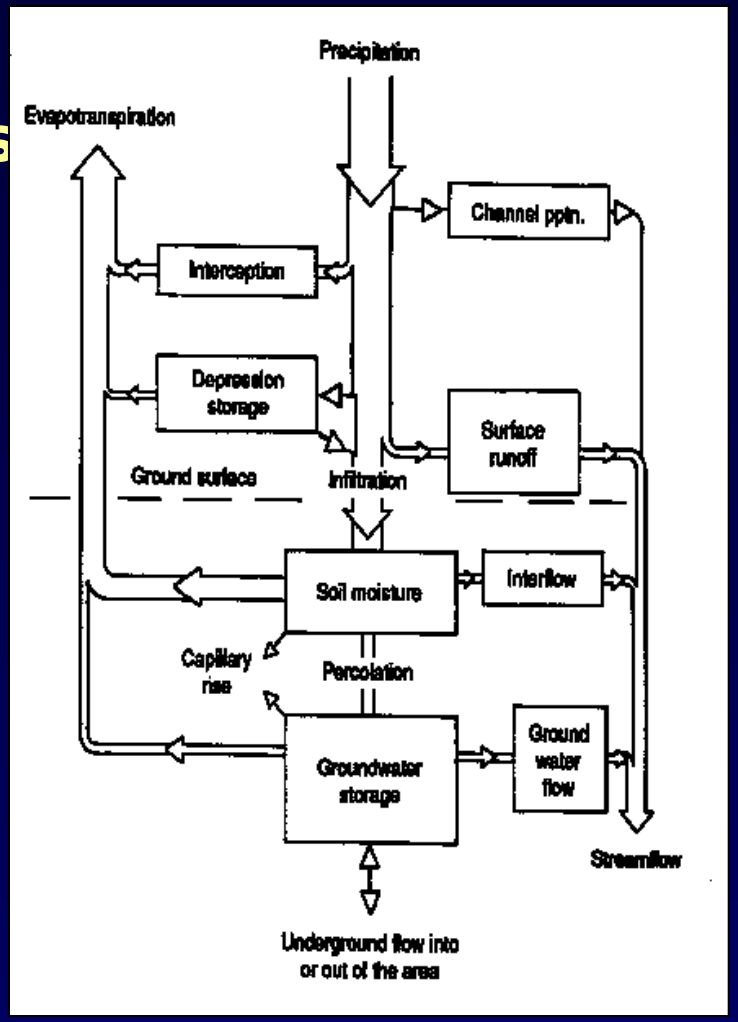
PERLND	simulate a pervious land segment
IMPLND	simulate an impervious land se
RCHRES	simulate a river/reservoir reach

Utility Modules

COPY	transfer time series data
PLTGEN	output time series data for plotting
DISPLY	summarize time series data (tabular)
DURANL	perform duration analysis
GENER	combine or transform time series data
MUTSIN	input time series data from PLT
BMPRAC	simulate effects of simple BMPs
REPORT	report/summarize multiple time series

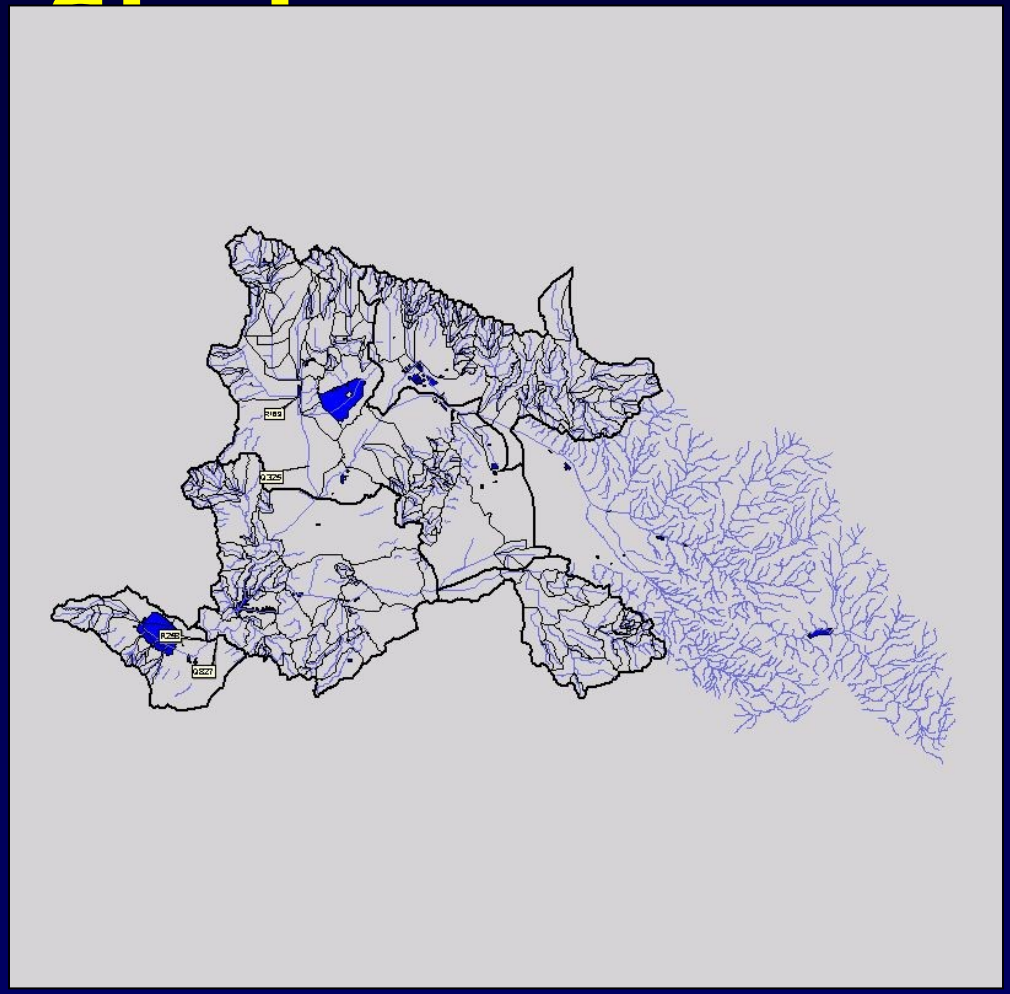
HYDROLOGIC COMPONENTS

- **Hydrologic Components**
  - **Rainfall or Snow**
  - **Interception**
  - **Depression storage**
  - **Evapotranspiration**
  - **Infiltration**
  - **Surface storage**
  - **Runoff**
  - **Interflow**
  - **Groundwater flow**



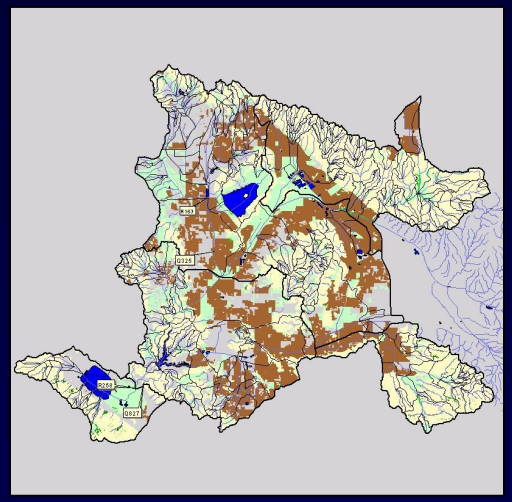
San Jacinto Watershed

- Lower Model is Approximately 480 sq. miles.
- 272 Stream Reaches
- 51 PERLNDS
- 5 IMPLNDS
- Discharge
- Sediment
- Nutrients
- Existing, Projected, and Historical LULC
- Will be used by ecologists to better estimate ecological health of the system.

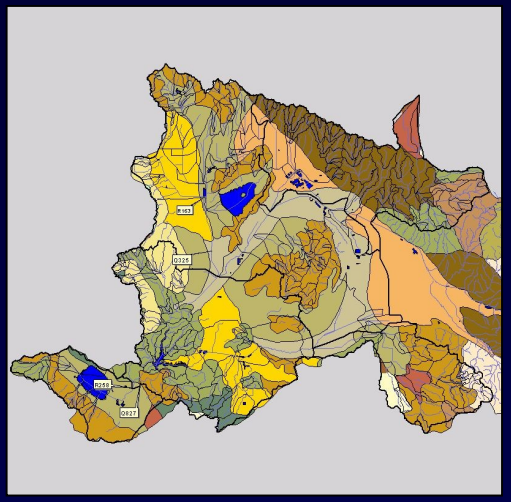


DC Billy Johnson ERDC-EL and Brian Skahill ERDC-CHL

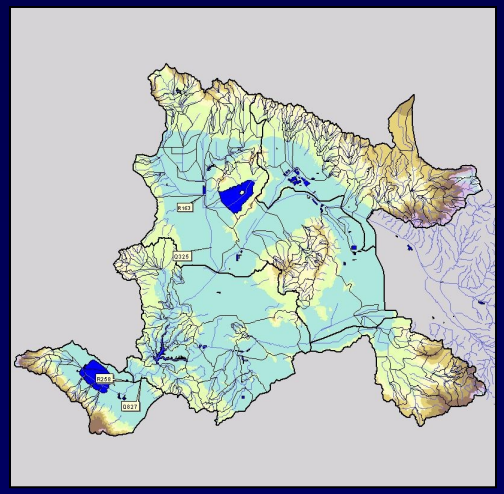
San Jacinto Watershed – Case Study



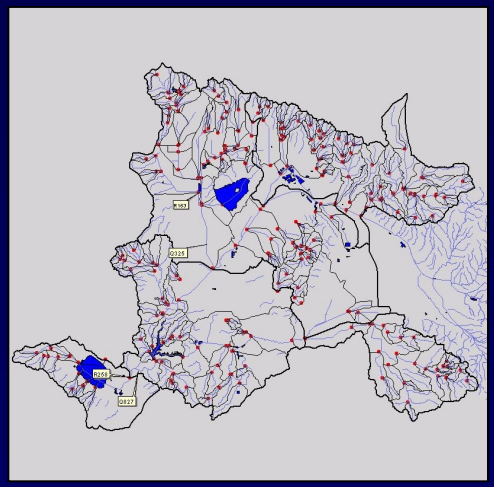
Existing Land Use



STATSGO Soil Data



USGS DEM data



Hydrograph Computation Points

San Jacinto Watershed

Time Series Data

- **Precipitation**
- **Evaporation**
- **Temperatures**
- **Diversion Flows**
- **Observed Flows and Concentrations for Calibration and Validation**

Original photo

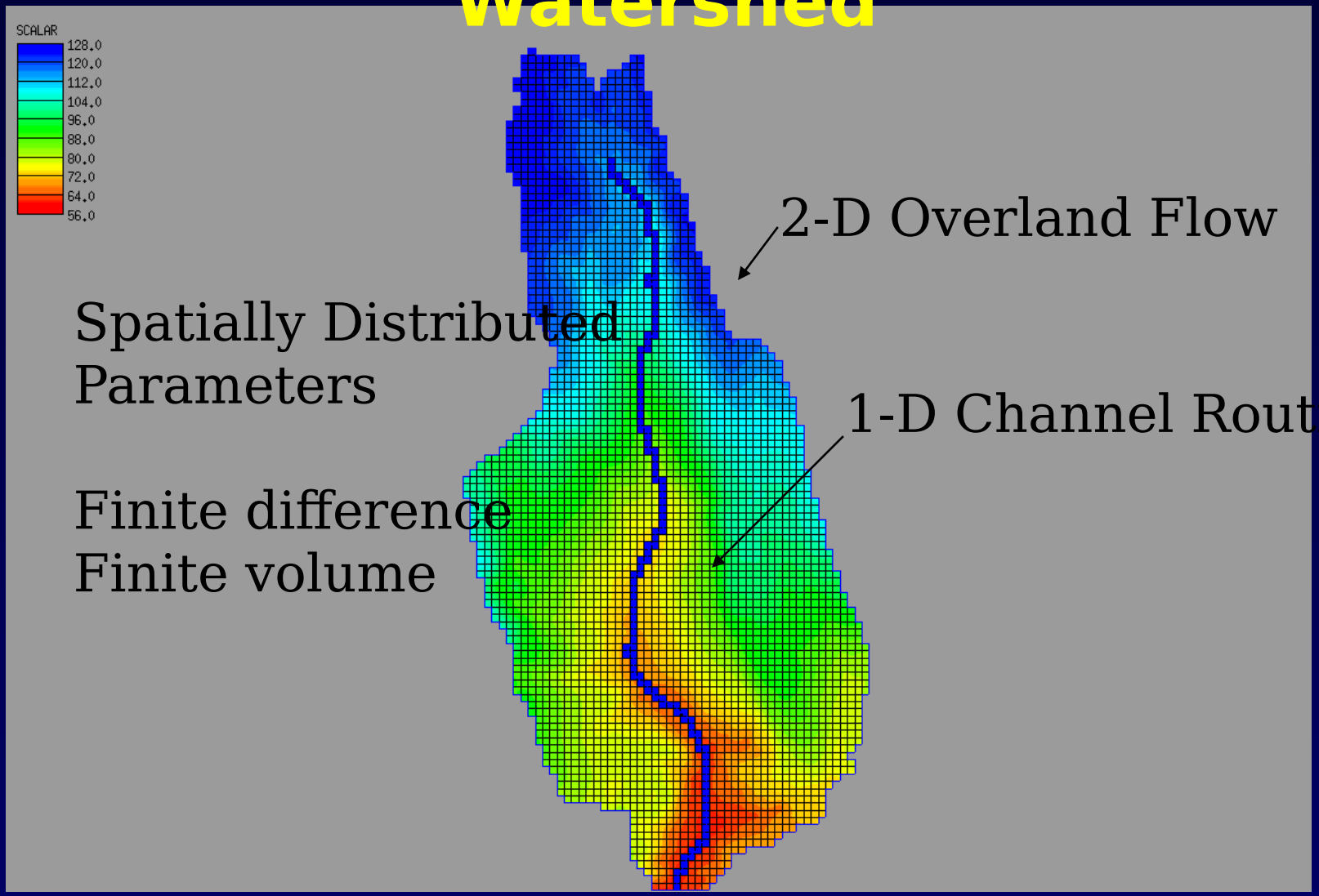
Physically-based, Distributed Models

- Subdivide the watershed into elements
- Assign parameter values to each element
- Model processes at the element level
- Integrate elemental response to produce watershed response to inputs

Physically-based, Distributed Models

- Advantages
  - models physical processes
  - includes spatial heterogeneity
  - requires less calibration
  - extendable beyond range of calibration
- Disadvantages
  - data requirements
  - computational penalty
- Example
  - GSSHA

Two-dimensional (2-D) Structured Grid Popular Creek Watershed



Applicability

- Watersheds with minimal calibration data
- Analyze land use or climate change, project alternatives, or any conditions beyond the range of calibrated values.
- Inherently distributed processes - sediment erosion and deposition, non-point source pollution, surface water/groundwater interaction

Gridded Surface Subsurface Hydrologic Analysis (GSSHA)

- Distributed spatial model
- Option/process driven model
- Processes are selected and sufficient data must be provided to drive the selected options
- Reformulation and enhancement of CASC2D
- Verifiable at both process and watershed scales

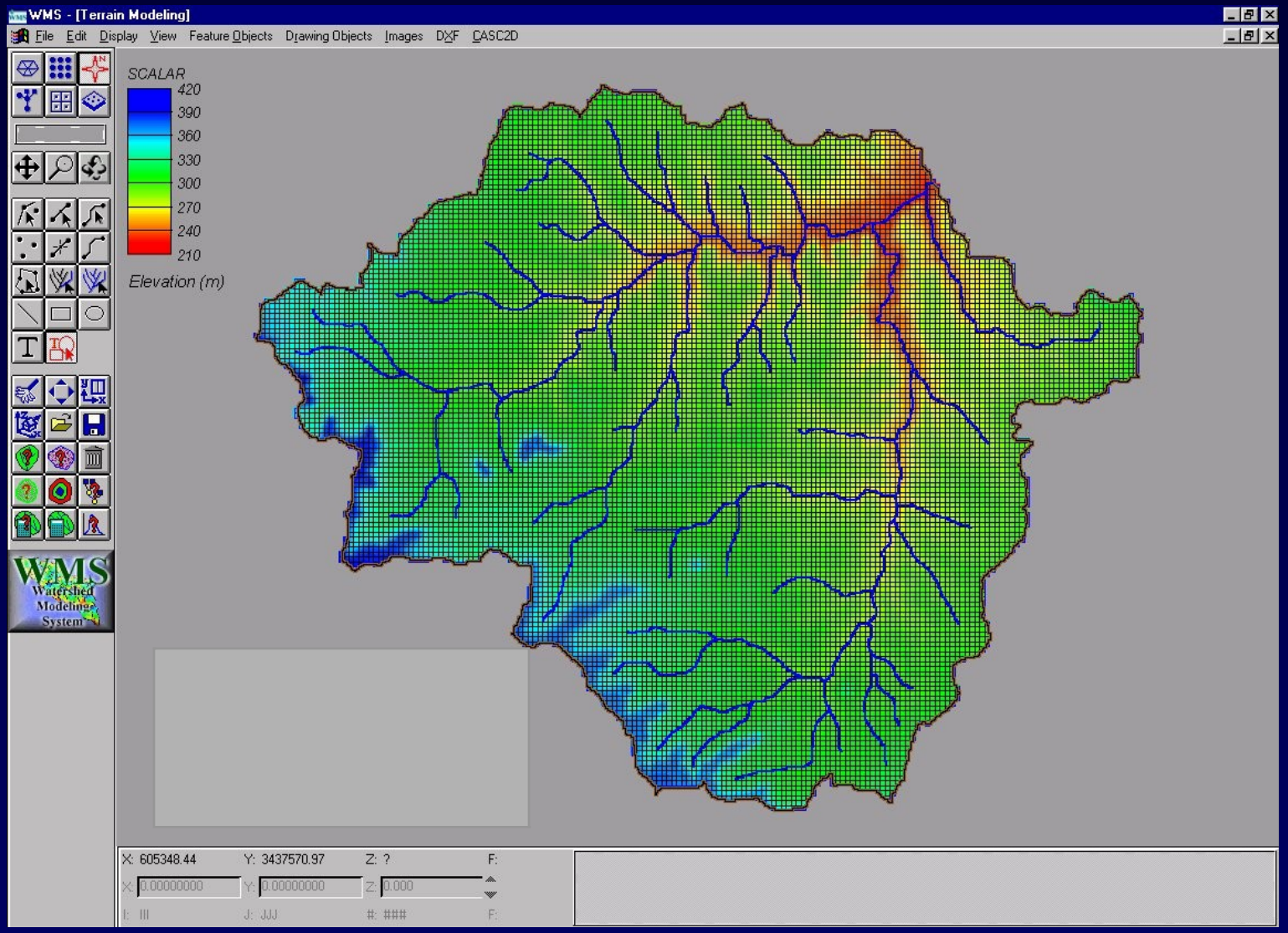
GSSHA Process Modeling Cell Level Processes

- Spatial and temporal distribution of precipitation
- Snowfall accumulation and melting
- Plant interception of precipitation
- Micro-topography surface retention of water
- Infiltration
- Unsaturated soil water movement
- Evapo-transpiration (ET)
- Sediment erosion and deposition

GSSHA Enhancements

- Sediment erosion, transport, and deposition
  - Currently uses empirical method used in CASC2D-SED
  - Physically based formulation is under development (RSM)
    - Focus on energy inputs from flow, slope, and rainfall impact
    - Use advection-dispersion equation with erosion and deposition as source and sink terms
- Calculation of TMDLs and NPSP (SMART)
  - Initially simulate nutrients and inter-species reactions
  - Nutrient uptake, decay, and inter-species reactions will be determined based on conditions in the watershed
- Development of routing for subsurface pipe networks such as combined sewer overflows (TOWNs)

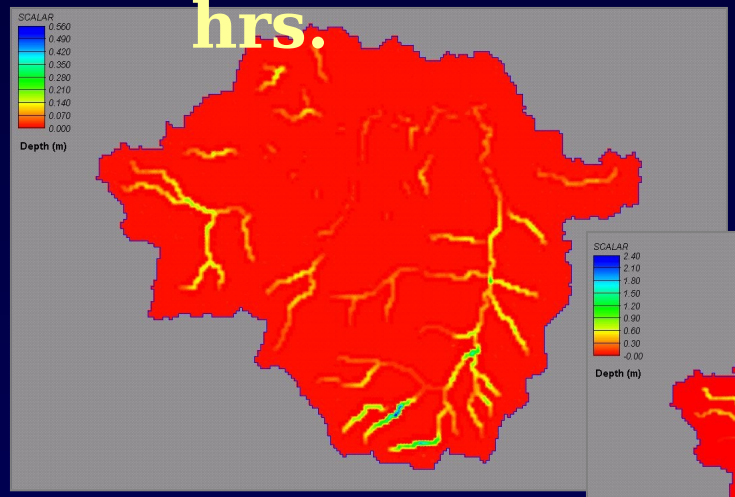
GSSHA Computational Grid



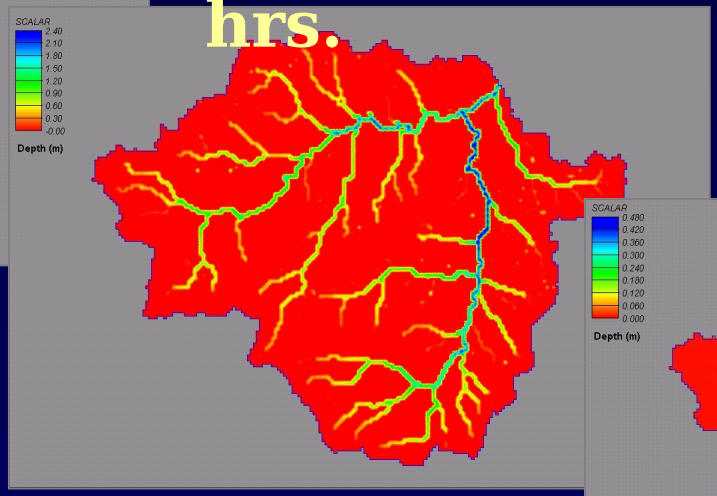
GSSHA Results

Surface Flow Depth

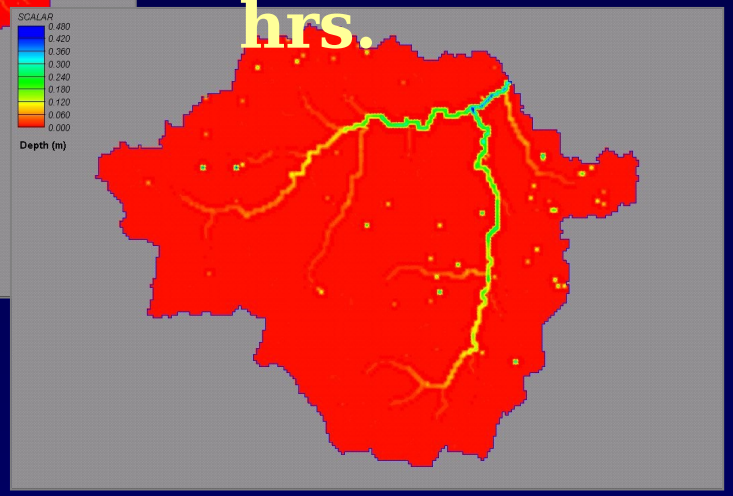
Time = 3 hrs.



Time = 5 hrs.



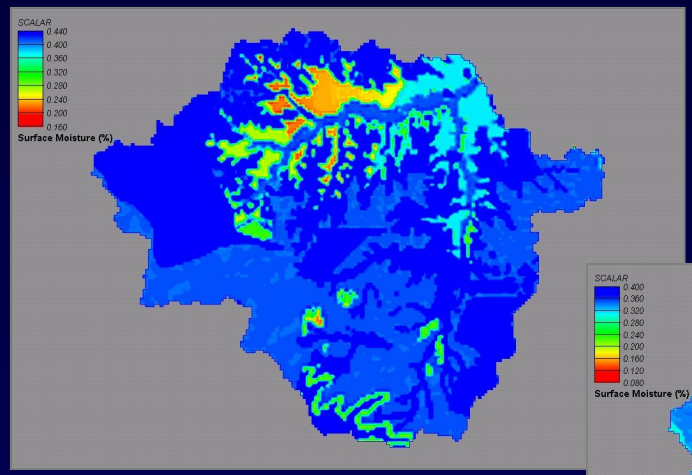
Time = 7 hrs.



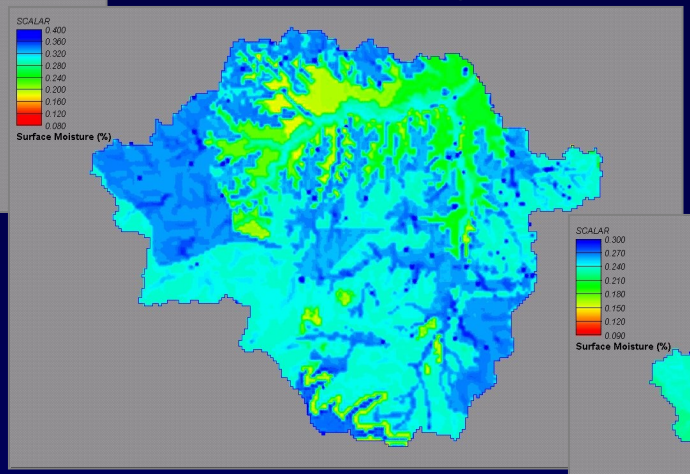
GSSHA Results

Surface Soil Moisture

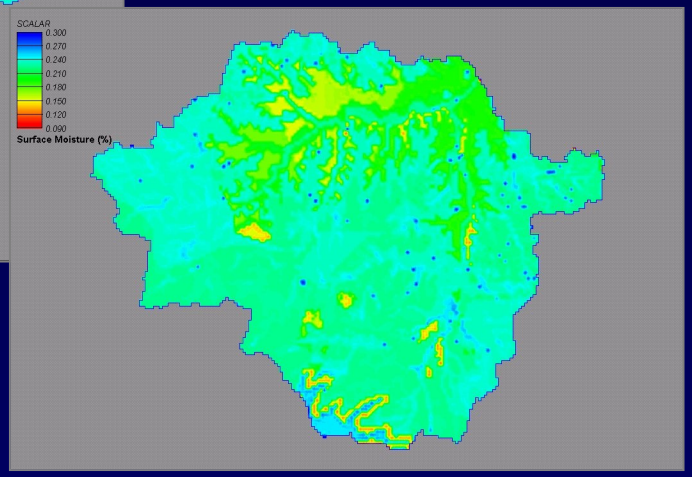
End of



+ 1 day



+ 3



Original photo (sort of)

CE-QUAL-W2

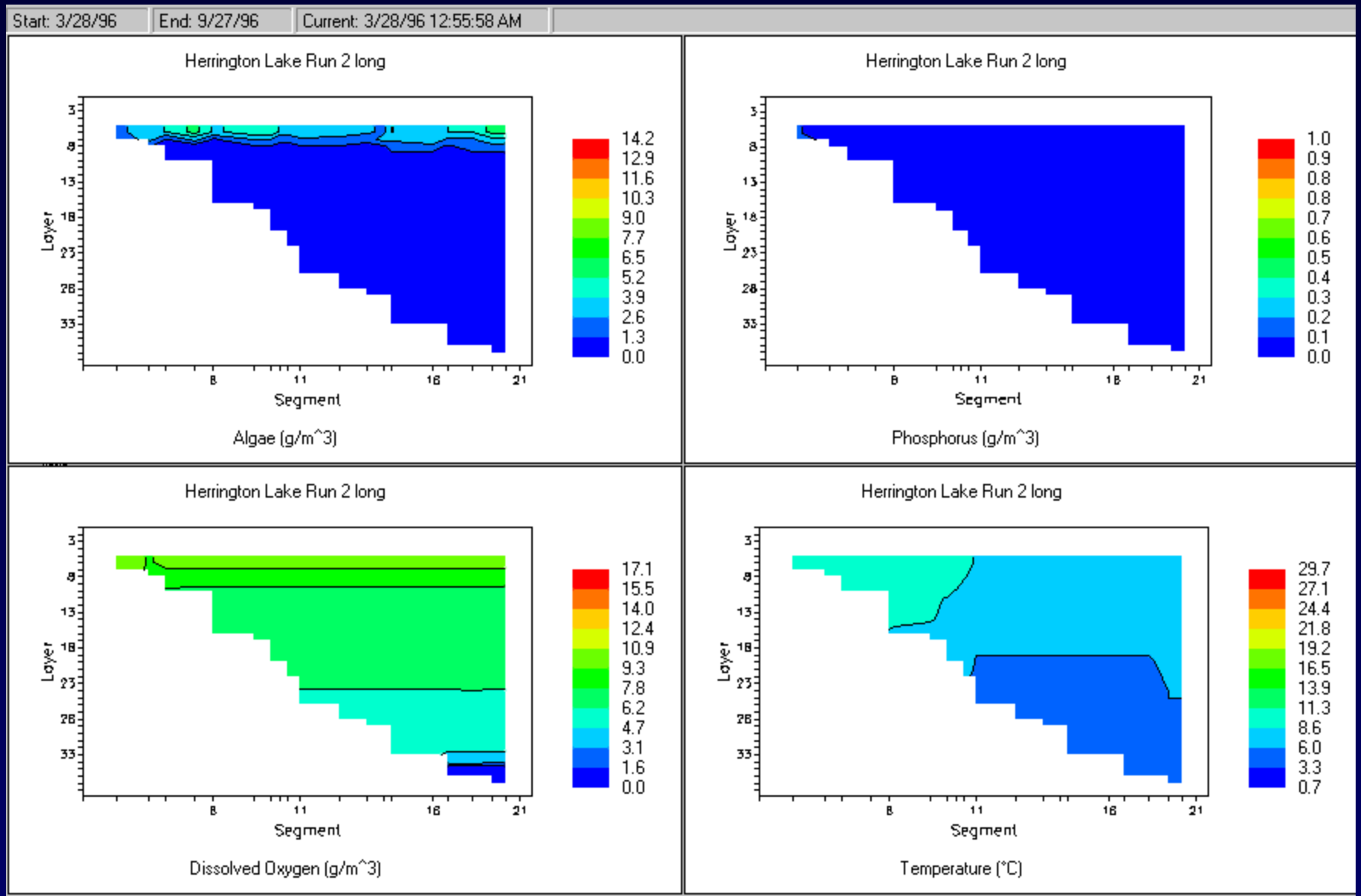
2D laterally averaged hydrodynamic and water quality model. This model has been applied to rivers, lakes, reservoirs, and estuaries.

- **Predicts water surface elevations, velocities, salinity, and temperatures with density effects on hydrodynamics**
- **WQ algorithms incorporate 21 other water quality constituents including nutrient/phytoplankton/dissolved oxygen (DO) interactions under aerobic and anoxic conditions.**
- **Variable segment lengths and layer thicknesses can be used thus allowing for more resolution where needed.**
- **Multiple Inflows and Outflows.**
- **Ice Cover calculations.**
- **Selective Withdrawal calculations.**
- **Allows for long-term time varying boundary conditions.**

POC Tom Cole – ERDC/EL

CE-QUAL-W2

Water Quality Simulation

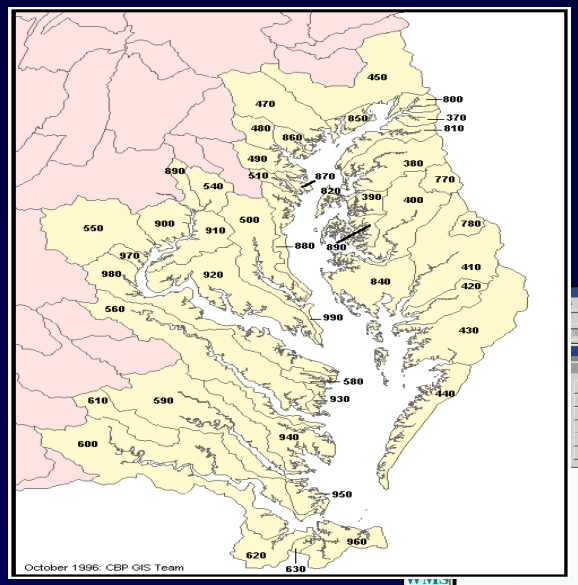


CE-QUAL-W2

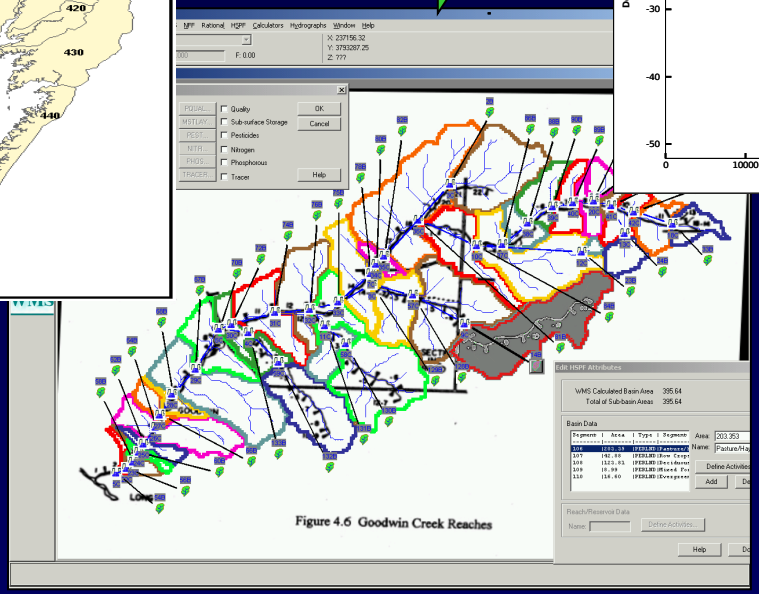
Strengths

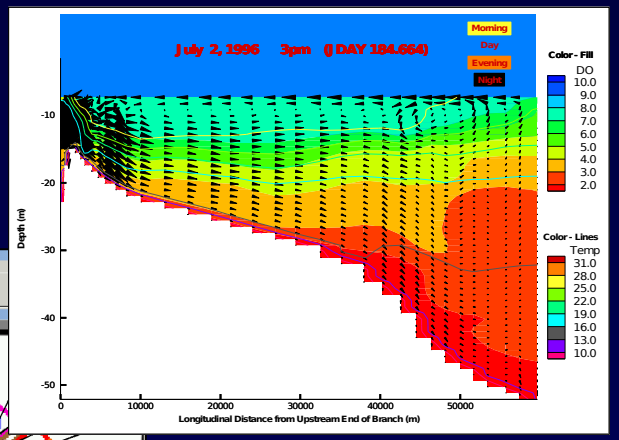
- 2D Laterally Averaged Hydrodynamics
- Performs Hydrodynamic and Water Quality Simulations
- Links multiple Reservoirs and Channels into one model
- Continuous Simulation (Long-Term)
- Allows for easy use of GIS data (WMS and ArcView Tools)
- User Friendly setup

HSPF Linked to CE-QUAL-W2



HSPF





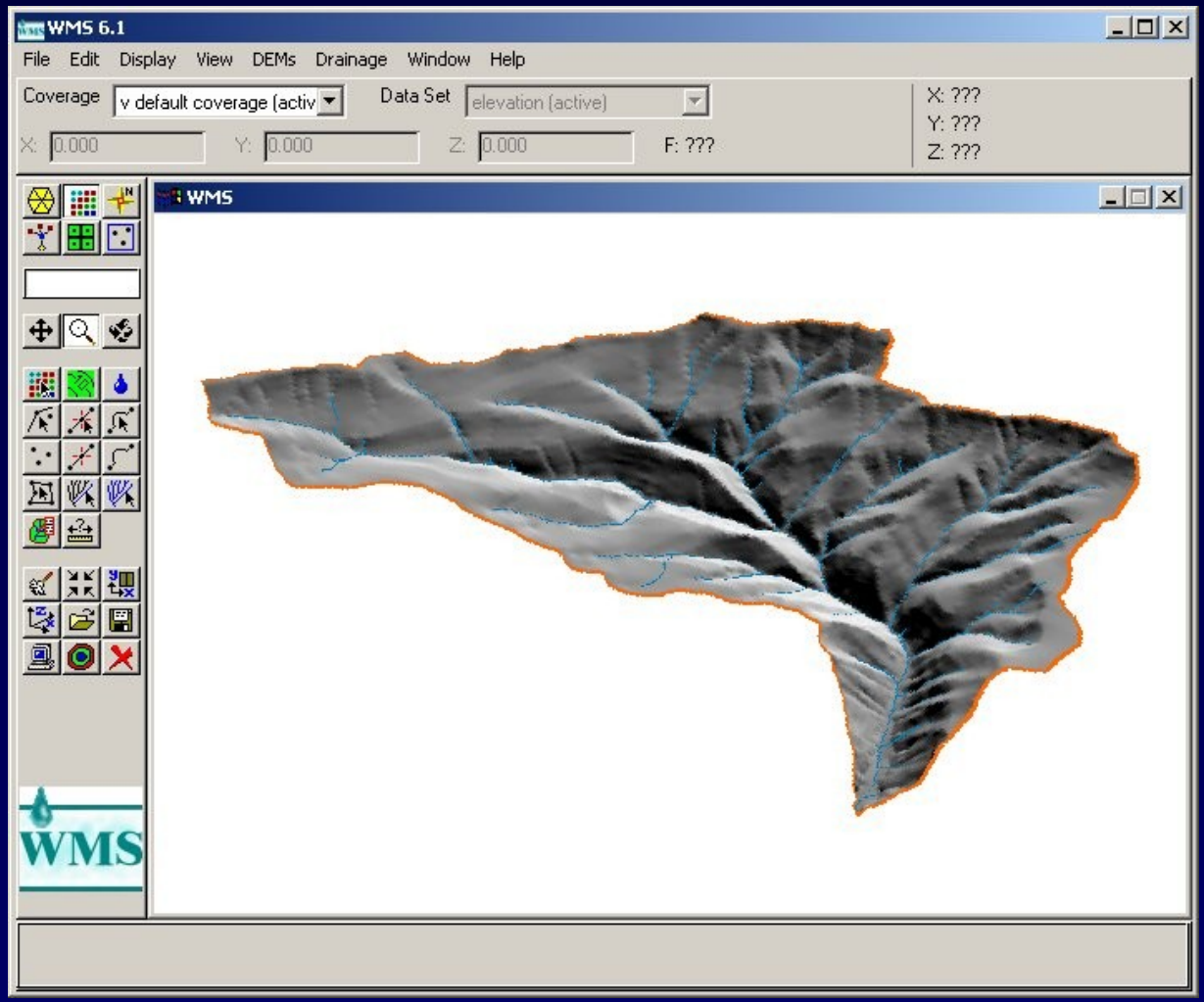
CE-QUAL-W2

OC Billy Johnson – ERDC/EL and Tom Cole ERDC/EL

Applications

- Watershed Planning
- TMDL Assessments
- Lake Water Quality Manageme
- Technical Coordination
- Public Communication

Watershed Modeling System (WMS)



ERDC
Engineer Research and Development Center

Modeling Approach

- Graphical user interface (GUI)
- Common visualization and data manulipation tools
- Multiple computational models and modeling approaches supported
  - Empirically based, lumped parameter models
  - Physically-based, distributed spatial parameter models
  - Single event models
  - Continuous models
- Integrates multiple data sources to automate model parameter definition
- Integrates directly with GIS through ArcObject

Supported Models

- NFF
- TR-20
- TR-55
- HEC-1/HEC HMS
- HSPF
- Rational Method
- MORDAT
- GSSHA
- CE-QUAL-W2

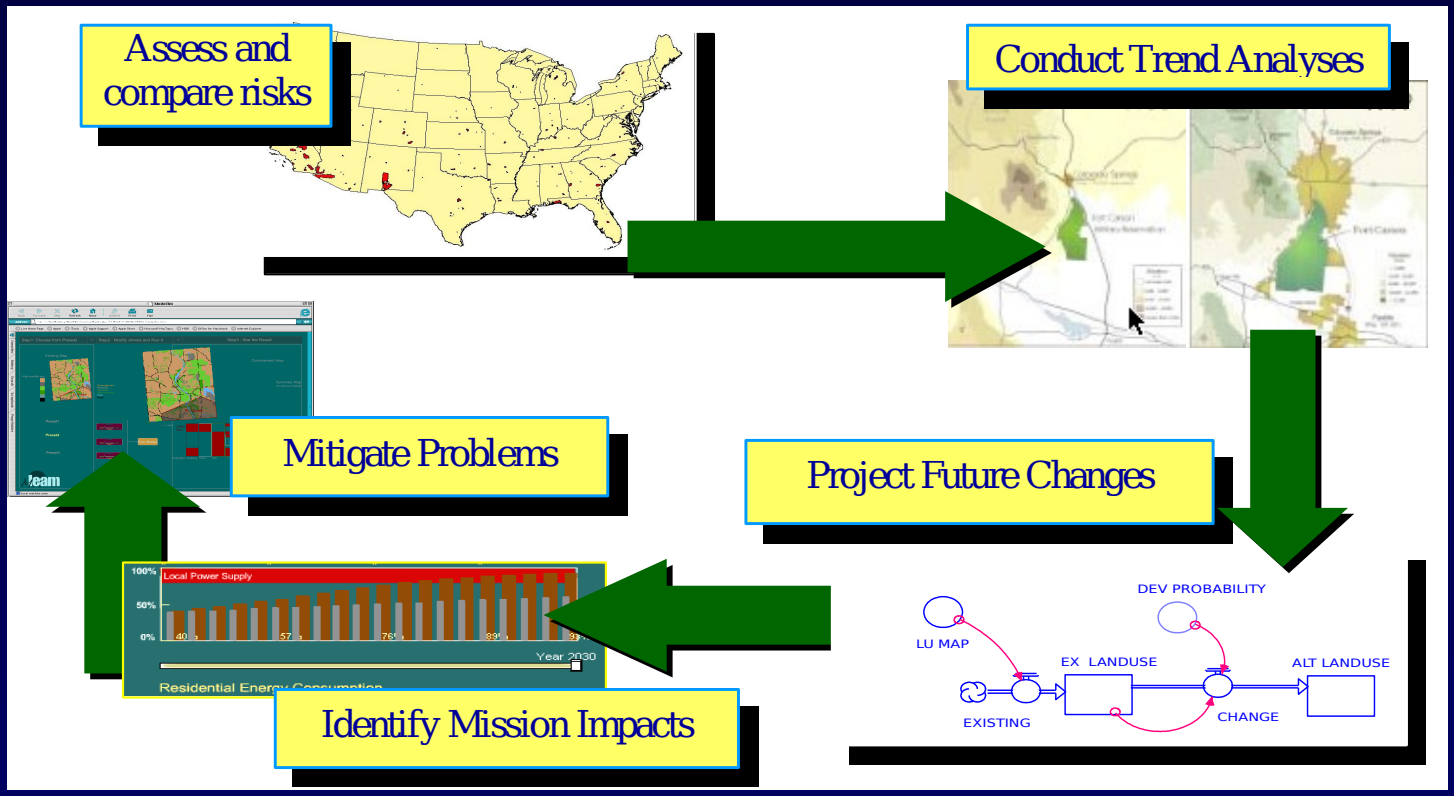
General Model Input Required

- Model Control Parameters
- Topography
  - Drainage Area
  - Slope
- Abstractions or Losses
  - Evapotranspiration
  - Infiltration
  - Ponding
- Routing Parameters
  - Overland
  - Channel
- Ponds, Diversions, Special Features
- Precipitation

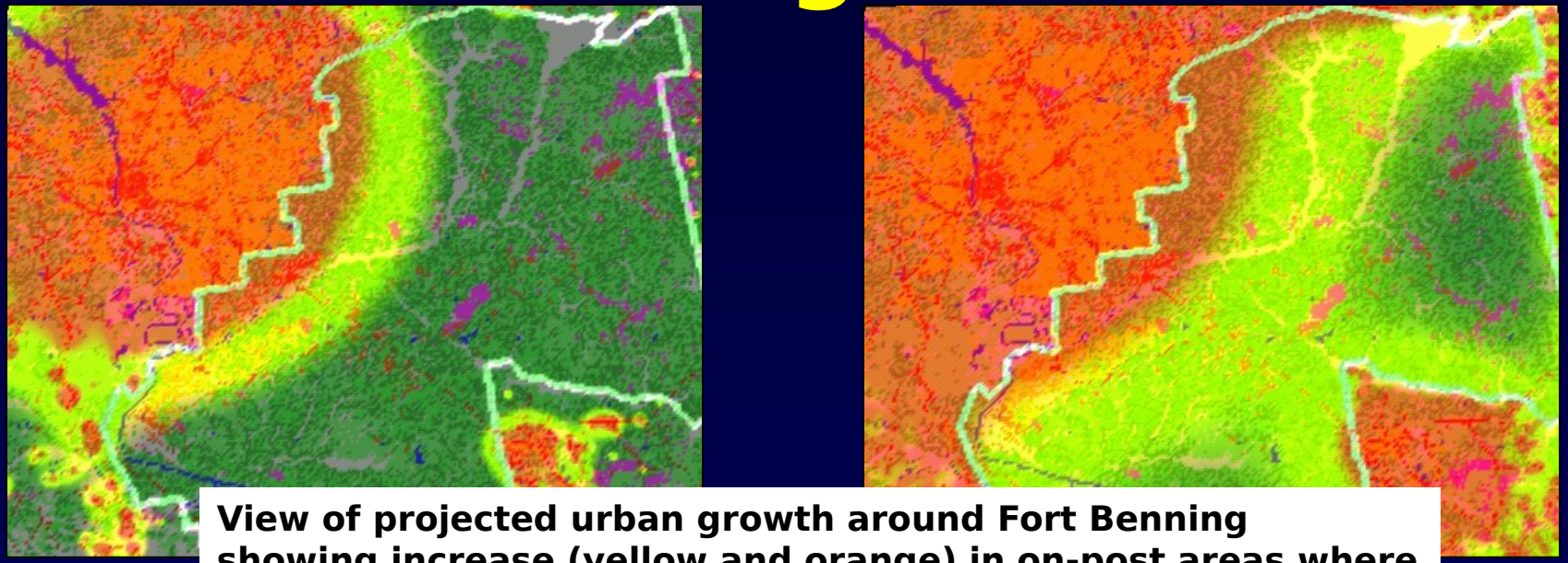
Original photo

Urban Growth Models

LEAM – Land use and Evolution impact Assessment



Linked Models for Watershed Management

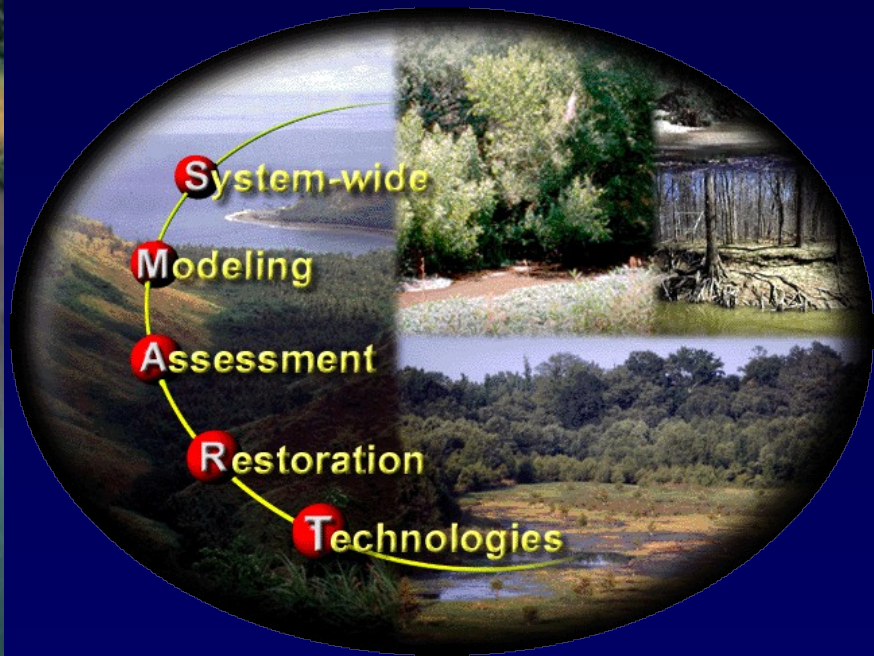


View of projected urban growth around Fort Benning showing increase (yellow and orange) in on-post areas where activities may generate noise complaints.

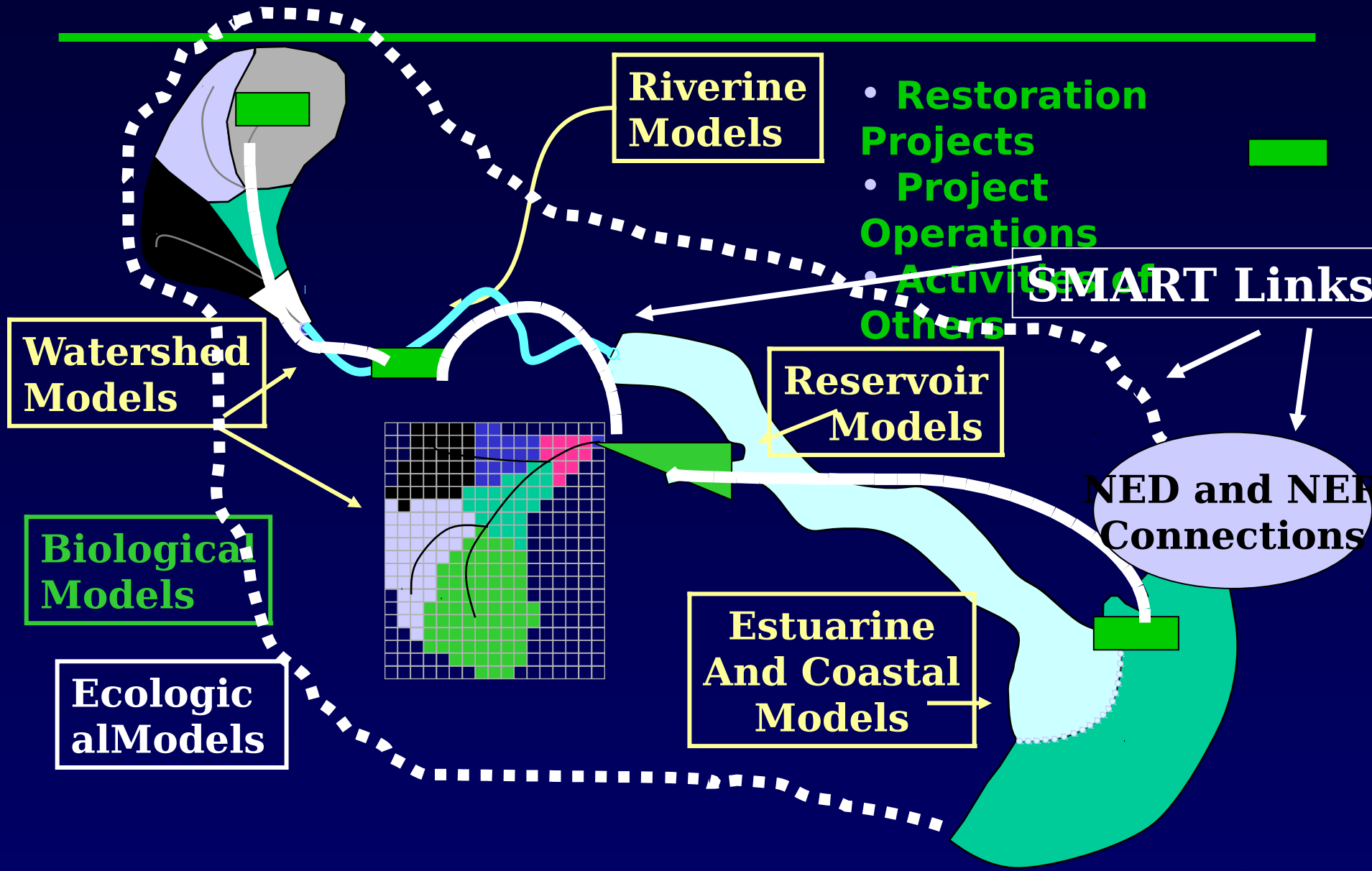
Proposed for Atlanta (multi-county
LEAM – HSPF – CE-QUAL-W2
Urban – Runoff – Lake Response

System-wide Watershed Management

“Mountains to the Sea”



Example of a SMART Application



SMART Modeling and Methods Suite

Watershed Models
HSPF
GSSHA
WASH123D
ADH

Links to Others
SWAT, SPARROW, WEPP

Planning/Economic Models
Conceptual Models
IWR-PLAN

Riverine Models
RMA2
HEC-2
HEC-RAS
CE-QUAL-RIV1
CE-QUAL-W2
ADH

Habitat and Ecological Function Models
EDYS
EFM
FQA
HEP
HSI species
HSI communities
HGM
IBI
RBP
RCHARG

Modeling Systems
HMS
WMS
SMS
GMS

Links to Other Modeling Systems
BASINS

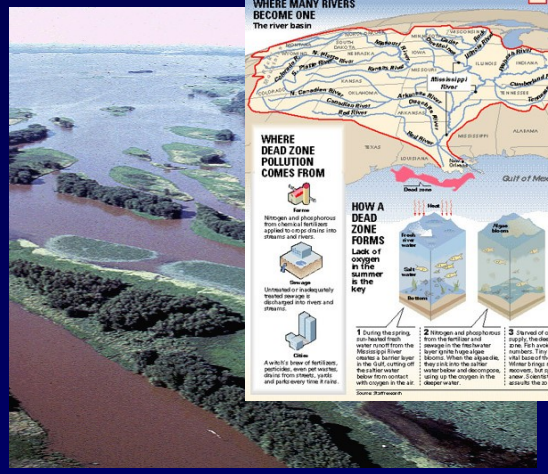
Reservoir Models
CE-QUAL-W2
ResSim

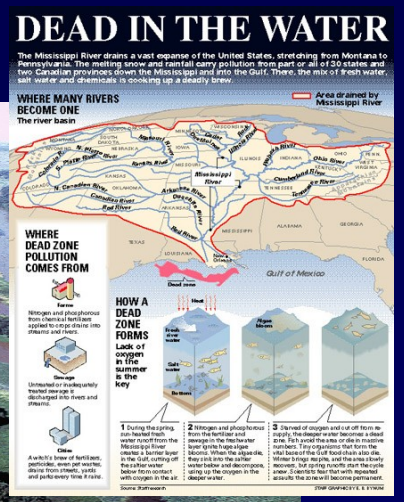
Urban Growth Models
LEAM
RSIM

Estuarine and Coastal Models
CE-QUAL-W2
ADH
CH3D
ICM
RMA4
TABS

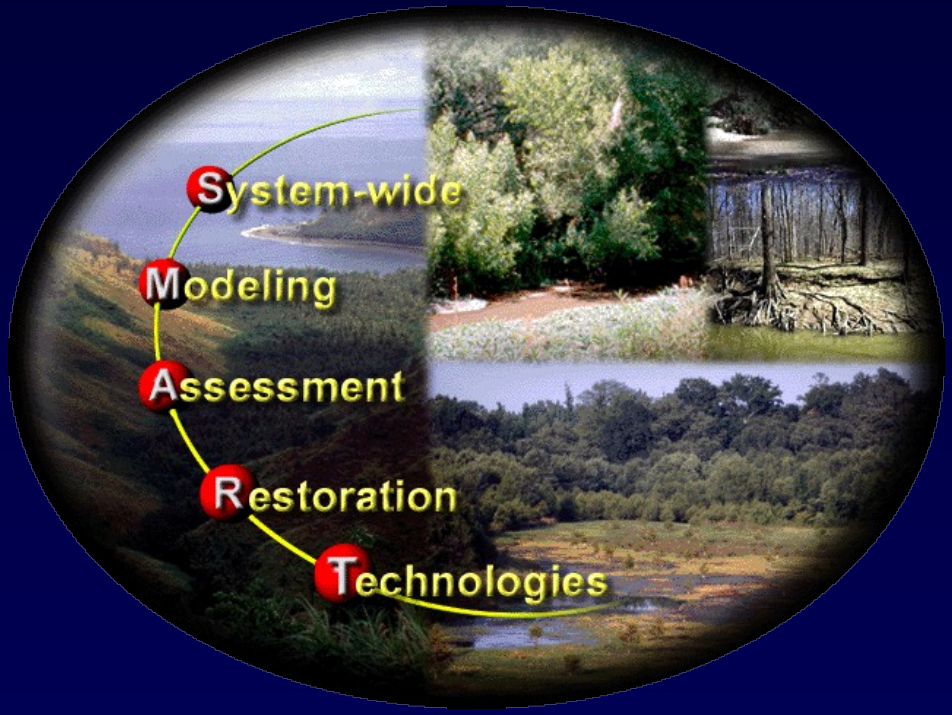
Potential Applications to Comprehensive Resource Management Needs

- WRDA authorities directed towards ecosystem restoration (e.g. Big Bear Lake (SPL) and Allatoona Lake (SAM)
- Upper Mississippi River
- South Florida/Everglades Restoration Project
- Louisiana Coastal Area (LCA) Restoration Study
- Gulf of Mexico – Hypoxic Zone
- Other (Permitting, SAMPs)




DEAD IN THE WATER
The Mississippi River drains a vast expanse of the United States, stretching from Montana to Pennsylvania. The melting snow and rainfall carry pollution from part or all of 30 states and two Canadian provinces down the Mississippi and into the Gulf. There, the mix of fresh water, salt water and chemicals is cooking up a deadly brew.
WHERE MANY RIVERS BECOME ONE
The river basin
Area drained by Mississippi River
Gulf of Mexico
WHERE DEAD ZONE POLLUTION COMES FROM
HOW A DEAD ZONE FORMS
Lack of oxygen in the summer is the key

System-wide Modeling, Assessment, and Restoration Technologies (SMART) Program



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ERDC Engineer Research and Development Center

Technical Assistance Programs

WOTS – Water Operations Technical Suppor
Robert C. Gunkel (Program Management)
Robert.C.Gunkel@erdc.usace.army.mil

DOTS – Dredging Operations Technical Sup
Doug Clarke (Program Manager)
Douglas.C.Clarke@erdc.usace.army.mil

and in Conclusion …

What can I learn from you?

Planners are doing very well
What can ERDC do for you?

What can I add to this course?
“I’m from the Government and I am